3-Point Stepper Control with PID 3Step

SIMATIC S7-1500

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SIMATIC S7-1500
3-point stepper control with PID 3Step

PID_3Step Technology Object

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Preface

Objective of the application

The application on hand uses the example of a mixer to illustrate the application of the integrated 3-point stepper control of the S7-1500 automation system.

Core topics of this application

The following main points are discussed in this application:

- Configuring the 3-point stepper controller
- Programming the 3-point stepper controller
- Commissioning the 3-point stepper controller
- Operating the 3-point stepper controller via a control panel

Advantage

The application of the (TO) PID_3Step technology object has many advantages.

- **PID control**
  - Simple programming with configurable blocks.
  - Simple commissioning through automatic calculation of the control parameters for optimal control quality and clear signal monitoring with trace function. Additional support by automatic transition time measurement of the actuator.
- **Integrated PID control**
  Specialized stepper controller for integrated actuators (e.g. valves).
- **Auto tuning**
  Innovative auto tuning with two different tuning methods for automatic calculation of the control parameters: pretuning and fine tuning during runtime.

The same advantages also apply for the PID_Compact (controller for continuous controlled systems).

Benefits

- No additional hardware and software required.
- Time saving due to simple automatic control parameter optimization for optimal control quality (PID controller).

Table of Contents

1 Task

1.1 Overview

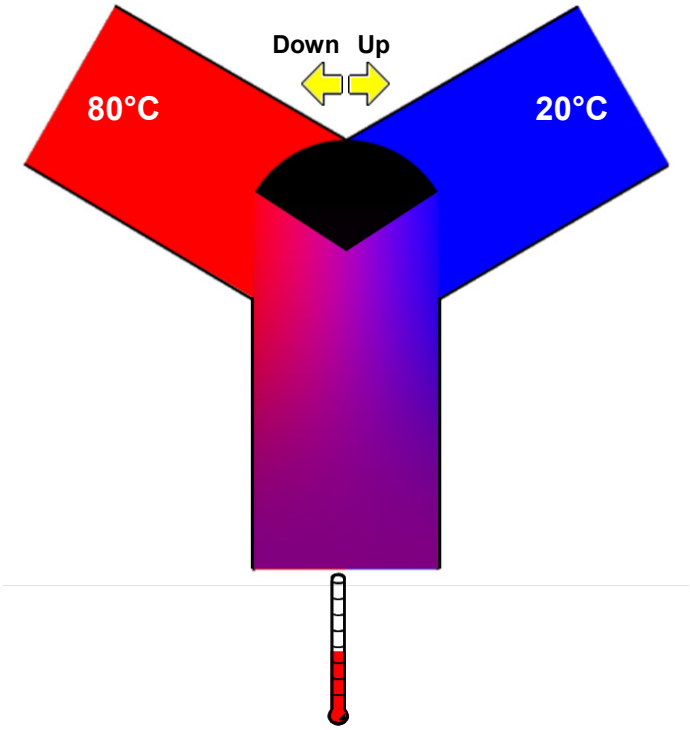
Introduction

The "PID_3Step" controller block shall control the valve of a mixer tap according to a desired given temperature.

Overview of the automation task

The figure below provides an overview of the automation task.

Figure 1-1 Overview of the automation task



Description of the automation task

A three-way mixing valve with valve actuator is used. One feed supplies hot water (e.g. 80°C) and the other one cold water (e.g. 20°C). Varying the water supply from 20°C to 80°C via the valve position can yield any water outlet temperature between these given temperatures.

This is referred to as a **3-point stepper control**:

1. The valve is controlled towards “more hot water” (digital output “Up”)

or

2. The valve is controlled towards “more cold water” (digital output “Down”)

or

3. The valve is not controlled at all.

2 Solution

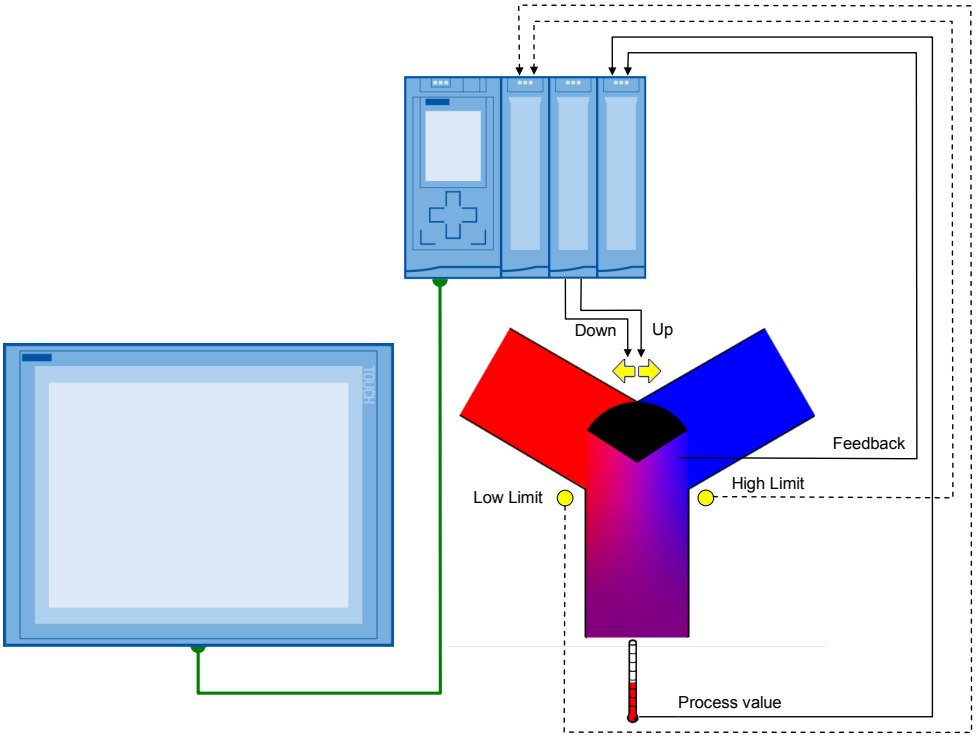
2.1 Solution overview

For SIMATIC S7-1500, the development environment STEP 7 V12 provides the “PID_3Step” 3-point stepper control block.
This instruction was especially developed for controlling valves or actuators with integrated behavior. It offers a simple and quick configuration and commissioning of your 3-point stepper control application.

Schematic layout

The following figure displays the most important components of the solution:

Figure 2-1 Overview of the overall solution



Within a control loop (here the mixer tap), the “PID_3Step” technology object continuously detects the measured actual value (the “Process value” temperature) and compares this value with the setpoint value (given via the TP1500 Comfort).

From the resulting control deviation, PID_3Step calculates an output value which enables the actual value to reach the setpoint value as quickly and stable as possible. The output value is converted into the digital control of the valve (“Up”/“Down”).

The output value of the PID controller is composed of the following fractions:

- **P fraction**
  The P fraction of the output value rises proportionally to the control deviation.
- **I fraction**
  The I fraction of the output value rises as long as the control deviation is balanced.
- **D-fraction**
  The D-fraction rises with increasing modification speed of the control deviation. The actual value is adapted to the setpoint value as quickly as possible. If the modification speed of the control deviation decreases again, the D-fraction also decreases.
- **Derivative time lag coefficient**
  The effect of the D fraction is delayed by the derivative time lag coefficient.
  Derivative time lag = Derivative time x Derivative time lag coefficient
  - 0.0: the D fraction is only effective for one cycle, hence, it is virtually ineffective
  - 0.5: in practice, this value has proven itself for controlled systems with a dominating time constant.
  - > 1.0: the larger the coefficient, the more the effect of the D fraction is delayed
- **Weighting of the P fraction**
  You can weaken the P fraction for setpoint value changes.
  Values from 0.0 to 1.0 are sensible
  - 1.0: P fraction fully effective at a setpoint value change
  - 0.0: P fraction not effective at a setpoint value change

  When changing the actual value, the P fraction is always fully effective.
- **Weighting of the D fraction**
  You can weaken the D fraction for setpoint value changes.
  Values from 0.0 to 1.0 are sensible
  - 1.0: D fraction fully effective at a setpoint value change
  - 0.0: D fraction not effective at a setpoint value change

  When changing the actual value, the D fraction is always fully effective.
- **PID algorithm scan time**
  Since the controlled system requires a certain time to react to a changed output value, it is sensible to not calculate the output value for each cycle. The PID algorithm scan time is the time between two output value calculations: It is determined during the optimization and rounded to a multiple of the scan time of the PID_3Step scan time. All other functions of PID_3Step are performed each time it is called up.
- **Deadband width**
  The dead band suppresses the noise fraction in the steady controller state. The deadband width specifies the size of the deadband. At a deadband width of 0.0 the dead band is switched off.

The “PID_3Step” instruction automatically calculates the P, I, and D parameters for your controlled system during pretuning. The parameters can be further optimized via fine tuning. You need not determine the parameters manually.

The 3-point stepper control is configured as follows:

- without end position feedback or valve position feedback
- with end position feedback of the valve only (Low & High Limit)
- with valve position feedback only (Feedback)
- with end position and valve position feedback

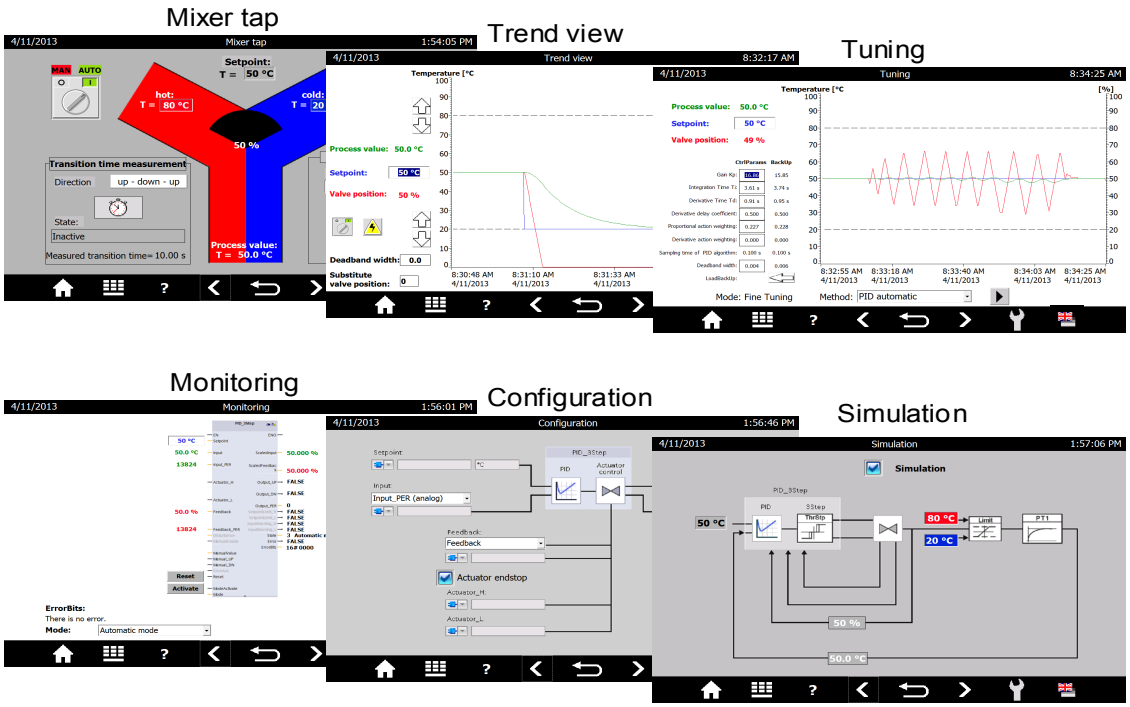
Note For more information on PID_3Step and PID_Compact refer to the Online Help of the TIA Portal.

2.2 Description of the core functionality

The core functionality of the application lies in the operation of the “PID_3Step” 3-point stepper controller via an HMI.

Overview and description of the user interface

Figure 2-2 Overview and description of the user interface



The operation of the application consists of the following 6 pictures:

- Mixer tap
- Trend view
- Tuning
- Monitoring
- Configuration
- Simulation

The operation of the screens is described in greater detail in chapter 6.

Advantages of this solution

The application enables you to use any configuration options and startup features via a TP1500 Comfort operator panel or via the HMI simulation integrated in WinCC V12 Basic.

This application offers you the following advantages:

- Switching between automatic and manual mode
- Transition time measurement of the valve
- Visualization of the valve position
- Trend curves of setpoint, actual value and manipulated variable
- Switching between the real controlled system and the simulation
- Disturbance variable control in simulation mode
- Specifying the behavior in the case of errors and their simulation
- Specifying the dead band width for energy saving operation
- Manually specified control parameter and automatic tuning
- Online monitoring of the “PID_3Step” controller block
- Modifying the configuration during runtime

Delimitation

This application gives you an overview of the “PID_3Step” technology object for operating a 3-point stepper controller via SIMATIC S7-1500 CPU.
You can adopt the application example to adjust your 3-point stepper control conveniently via TP1500 Comfort and adapt it to your automation task.

The application was tested via the simulation of the controlled system.
For the actual operation, the application example must be adapted to your used valve with actuator and temperature sensors used:

- Digital control in 2 directions or analog control?
- Required voltage and output for the control?
- Signal properties when feeding back the valve position or recorded end positions?
- Signal properties of the used temperature sensor?

The application is no substitute for the configuration screen of the PID_3Step wizard, since it defines the default values in the instance data block which are decisive for the restart after a power failure.

Apart from the “PID_3Step” control block, STEP 7 V12 also provides the “PID_Compact” for the SIMATIC S7-1500. This is a universally usable PID controller for continuous controlled systems. It also contains the advantages of automatic tuning, as well as the operating modes automatic and manual. According to the template of this application example, an HMI user interface can also be designed for the “PID_Compact”.

Required knowledge

Basic knowledge of control engineering and STEP 7 programming is assumed.

2.3 Hardware and software components used

The application was set up with the following components:

Hardware components

Table 2-1

Component	No.	Order number	Note
SIMATIC HMI TP1500 Comfort	1	6AV6647-0AF11-3AX0	Optional (can also be simulated via WinCC V12)
DI 32	1	6ES7 521-1BL00-0AB0	
DQ 32	1	6ES7 522-1BL00-0AB0	
AI 8	1	6ES7 531-7KF00-0AB0	
AQ 4	1	6ES7 532-5HD00-0AB0	optional
POWER SUPPLY DC28W	1	6ES7 505-0KA00-0AB0	
CPU S7-1516 3PN/DP	1	6ES7516-3AN00-0AB0	or alternatively a CPU S7-1511 or S7-1513
Three-way mixing valve with actuator motor and control for 2 directions	1	Valve manufacturer	Optional with digital end position feedback or analog valve position feedback (0 to 10V)
Temperature sensors protection class: IPX8 (permanent submersion) measuring range: 0 to 100°C	1	Electrical goods retailer	Executable as analog signal encoder, thermocouple or resistivity thermometer
Programming unit	1		With Ethernet connector
Ethernet line TP CORD RJ45/RJ45 2M	3	6XV1870-3QH20	
Miniature circuit breaker	1	5SX2116-6	1 pole B, 16A
S7-1500 mounting rail 482 mm	1	6ES7 590-1AE80-0AA0	

Standard software components

Table 2-2

Component	No.	Order number	Note
SIMATIC STEP 7 V12	1	6ES7822-1A.02-..	
SIMATIC WinCC V12	1	6AV210.-....2-0	

Sample files and projects

The following list includes all files and projects that are used in this example.

Table 2-3

Component	Note
68011827_S7-1500_PID_3Step_CODE_v10.zip	This zip file includes the STEP 7 project.
68011827_S7-1500_PID_3Step_DOKU_v10_en.pdf	This document

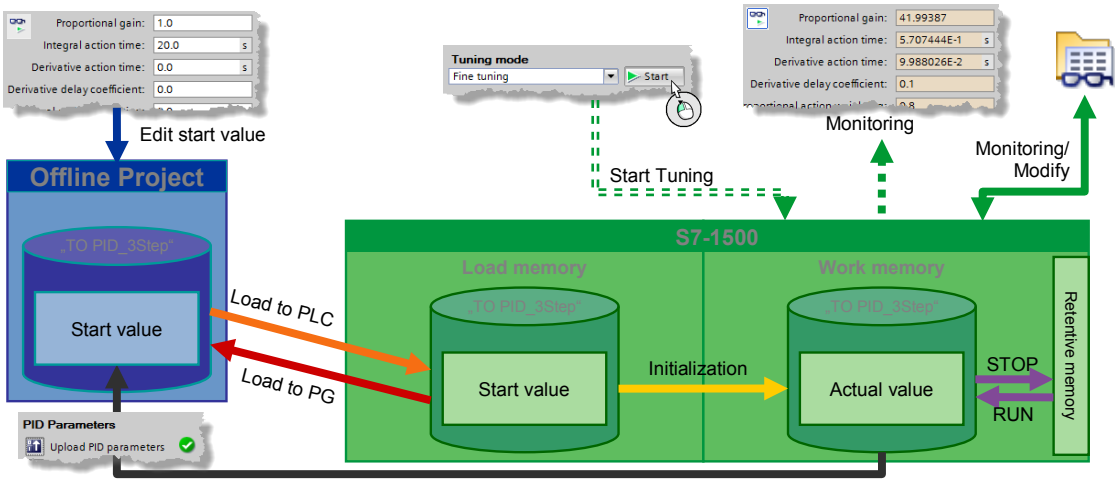
3 Basics

Overview of data management

Figure 3-1 shows an overview of the data management of the “PID_3Step” controller.

- For the PID Control technology objects start values are created for the PID parameters. The start values can be edited.
- During the download into the CPU, the offline project is first stored in the load memory.
- For the operating status transitions NETWORK ON → Startup and for STOP → Startup the variables of global data blocks, instance data blocks and technology objects are initialized with your start values. Retentive tags receive their actual values secured in the retentive memory.
- Tuning the PID parameters affects the actual values in the work memory.
- The “Monitoring / control” function also accesses the current values in the main memory.
- Clicking on the “Upload PID parameters” icon loads the tuned PID parameters into your offline project.

Figure 3-1 Data management overview

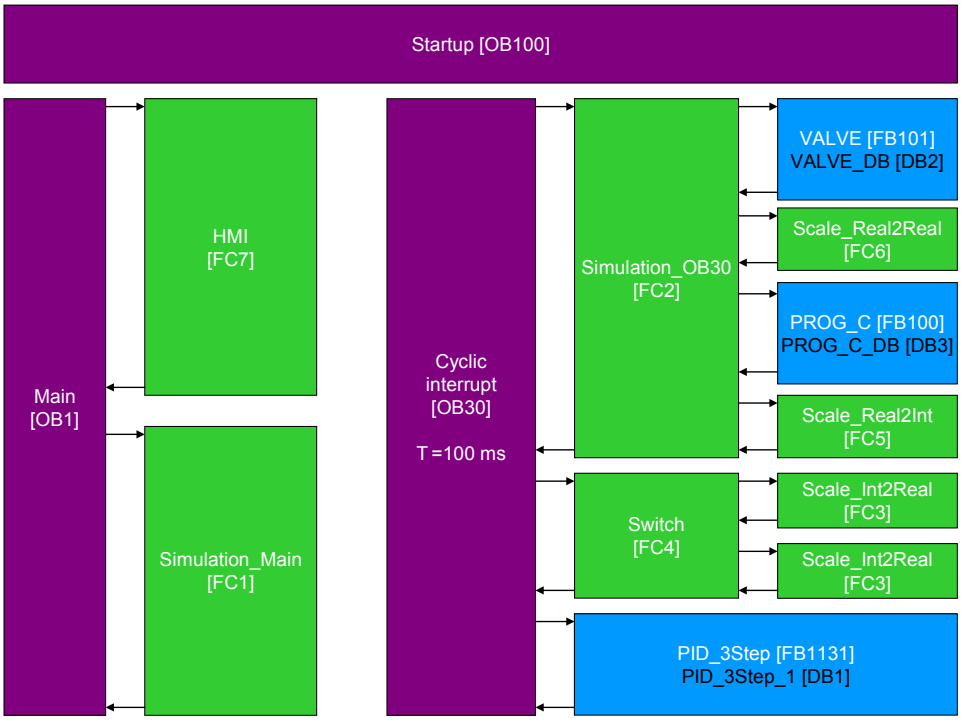


4 Function Mechanisms of this Application

General overview

Figure 4-1 shows the temporal sequence of block calls in the control unit of the application project.

Figure 4-1 Program structure overview



The control project part uses the following organization blocks:

- Startup [OB100] for initialization
- Main [OB1], from where the functions for the HMI transfer are called
- Cyclic interrupt [OB30], which calls the 3-point stepper controller cyclically every 100 milliseconds using the simulation blocks.

Instance data bocks and global data blocks are used for the parameter transfer between the functions.

Instance data blocks:

- PID_3Step_1 [DB1]
- VALVE_DB [DB2]
- PROG_C_DB [DB3]

Global data blocks:

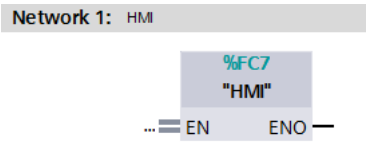
- Tags [DB4] (contains all tags not required for the simulation of the controlled system)
- Simulation_tags [DB4] (contains all tags required for the simulation of the controlled system).

4.1 Main [OB1]

The functions for the HMI transfer are called from the operation block “Main”.

4.1.1 HMI [FC7]

Figure 4-2 Calling the “HMI” function



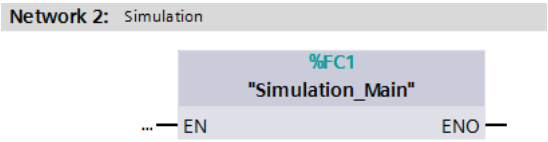
The “HMI” function defines tags which the TP1500 Comfort requires for the display, such as:

- Visibility tags
- Synchronization times
- Value transfers
- Feasibility conditions

Further descriptions are available in the network headers.

4.1.2 Simulation_Main [FC1]

Figure 4-3 Call of function “Simulation_Main”



The “Simulation_Main” function defines tags required for the simulation of the controlled system, such as:

- disturbance variables
- referencing
- visibility of simulation tags

Further descriptions are available in the network headers.

4.2 Cyclic interrupt [OB30]

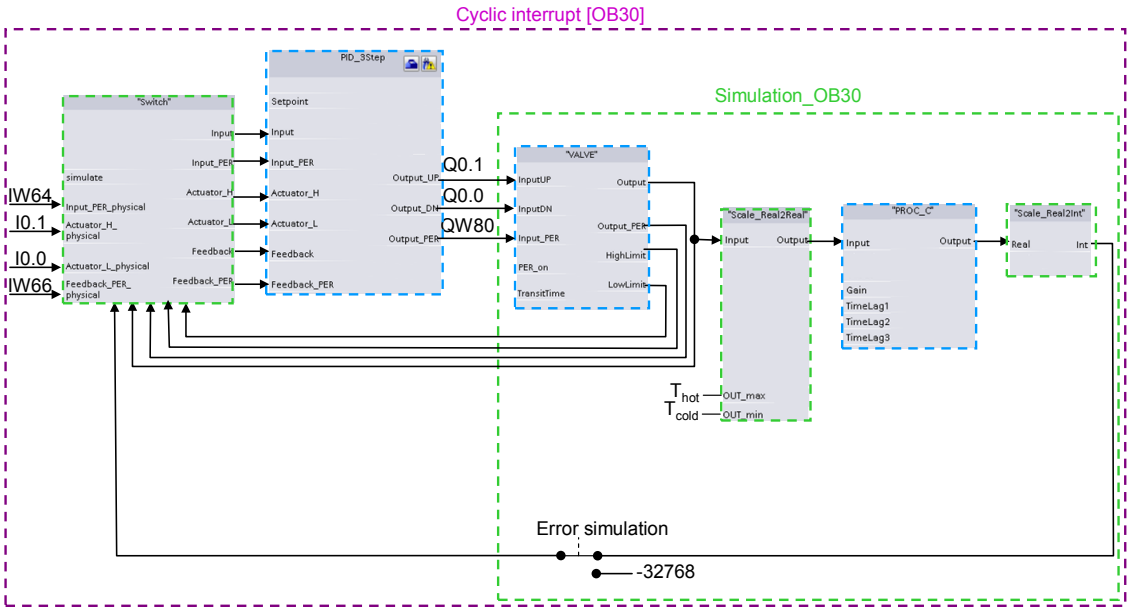
The actual program (the call of the “PID_3Step” 3-point stepper controller) occurs in the cyclic interrupt OB, since discrete software controls must be called up in a defined time interval for optimizing the controller quality.

100ms were set as a constant time interval for the scan time of OB30.

Program overview

In the cyclic interrupt OB the entire simulated control circuit is calculated.

Figure 4-4 Program overview “Cyclic interrupt [OB30]”



Explanation of the configuration

The “Switch” function enables you to switch between a real controlled system (signal evaluation via the control periphery) or a simulation of the controlled system.
The selected signals are then transferred to the “PID_3Step” 3-point stepper control as input parameters. From the control deviation = setpoint - actual value, depending on the PID parameters, it calculates the manipulated variable transferred digitally or analog to the I/O control outputs and the valve simulation block “VALVE”.
“VALVE” simulates the actuator and, depending on the traversing times, it calculates limit switch signals and the valve position, which are feed back internally to the “Switch”.
The valve position is, depending on the inflow temperatures T_{cold} and T_{hot}, converted to the temperature setpoint for the system via the “Scale_Real2Real” function.
The “PROG_C” block simulates a PT1 system behavior and outputs the actual temperature value,
The “Scale_Real2Int” function transforms the actual temperature value into an analog value.
For operating the error simulation, a faulty value is transferred to the “Switch” instead of the actual temperature value (-32768).

4.2.1 Switch [FC4]

The “Switch” function is used for switching between the signal evaluation via the control I/O and internally calculated simulated input signals for transfer at the “PID_3Step” 3-point stepper control.

Figure 4-5 Calling the “Switch” function

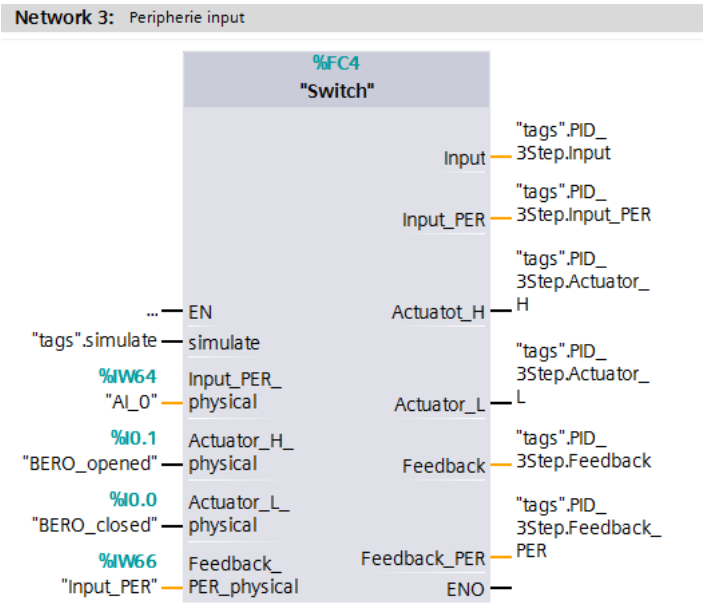


Table 4-1

	Name	Data type	Description
Input	simulate	Bool	FALSE = input parameter TRUE = internal simulation parameters are transferred to the outputs
	Input_PER_physical	Int	Analog I/O input signal for the actual value
	Actuator_H_physical	Bool	Upper limit switch signal of the valve
	Actuator_L_physical	Bool	Lower limit switch signal of the valve
	Feedback_PER_physical	Int	Analog I/O input signal for the valve position feedback
Output	Input	Real	Process value transfer to PID_3Step
	Input_PER	Int	Analog process value transfer to PID_3Step
	Actuator_H	Bool	Transfer of the upper limit switch signal to PID_3Step
	Actuator_L	Bool	Transfer of the lower limit switch signal to PID_3Step
	Feedback	Real	Transfer of the valve position feedback to PID_3Step
	Feedback_PER	Int	Transfer of the analog valve position feedback to PID_3Step

Note

Assign all inputs. This also applies if due to your controller configuration you do not need all of the inputs.

The simulated input variables are deliberately not directed outwards, since you only need to adjust the real I/O inputs to its hardware configuration.

For “simulate” = FALSE, the “Input” and “Feedback” parameters are calculated from the analog values “Input_PER” and “Feedback_PER” using the “Scale_Int2Real” function.

Scale_Int2Real [FC3]

The “Scale_Int2Real” function in function block “Switch” is used for converting an analog value (data type: Int) into a floating-point number (data type: Real) within predefined limits.

Figure 4-6 Calling the “Scale_Int2Real” function

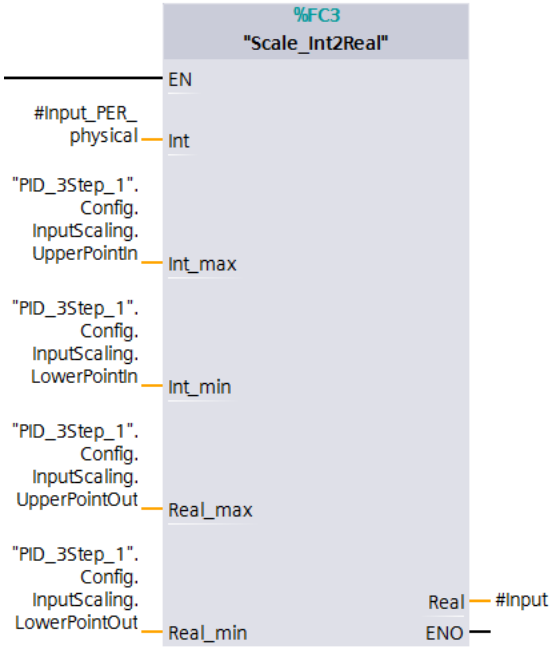


Table 4-2

	Name	Data type	Description
Input	Int	Int	Analog value to be converted
	Int_max	Real	Upper limit of the analog value
	Int_min	Real	Lower limit of the analog value
	Real_max	Real	Upper limit of the floating-point output value
	Real_min	Real	Lower limit of the floating-point output value
Output	Real	Real	Floating-point output value

Note

The specified input limits “Int_max” and “Int_min” are intentionally defined as “Real”, in order to guarantee the compatibility with the specified limits in the instance data block of “PID_3Step”.

4.2.2 PID_3Step [FB1131]

STEP 7 V12 provides the “PID_3Step” technology object with the installation. This function block was especially developed for controlling valves or actuators with integrated behavior.

Figure 4-7 Calling function block “PID_3Step”

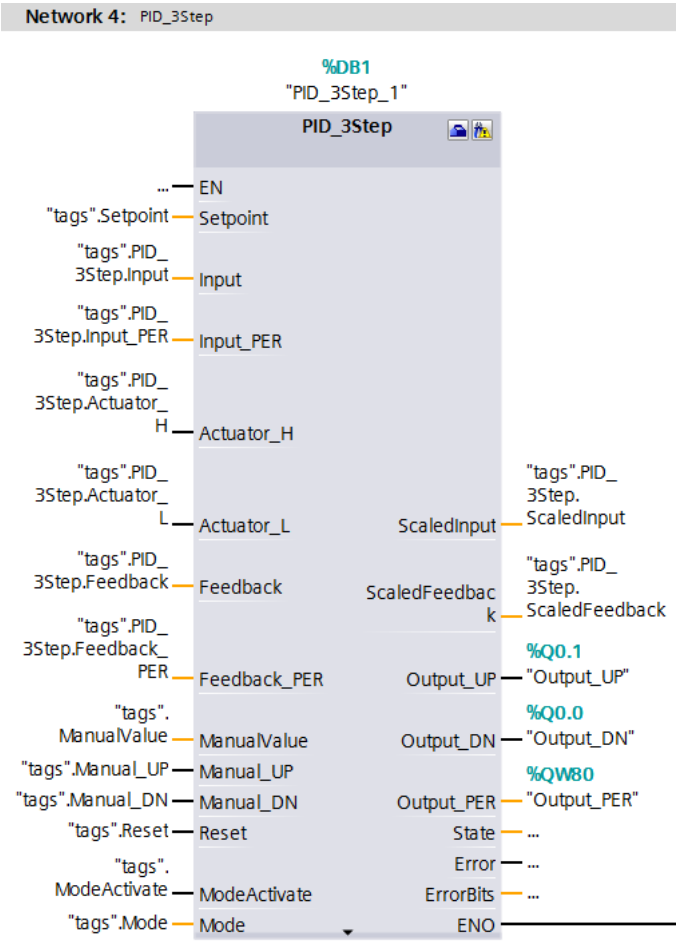


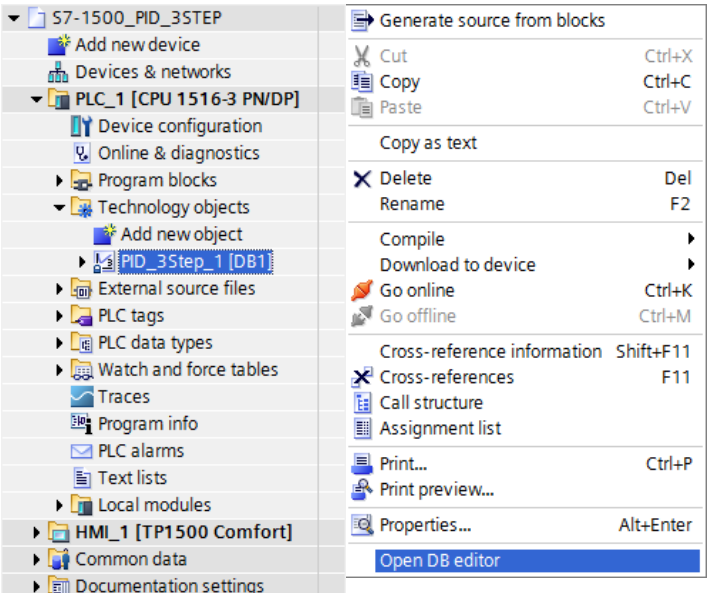
Table 4-3

	Name	Data type	Description
Input	Setpoint	Real	Internal setpoint value
	Input	Real	Actual value in REAL format
	Input_PER	Word	Actual value in I/O format
	Actuator_H	Bool	Actuator upper end stop
	Actuator_L	Bool	Actuator lower end stop
	Feedback	Real	External position feedback in REAL format

	Name	Data type	Description
	Feedback_PER	Word	External position feedback in I/O format
	ManualValue	Real	Manual value - only with analog output or feedback
	Manual_UP	Bool	Manual value up - edge triggered
	Manual_DN	Bool	Manual value down – edge triggered
	Reset	Bool	Restart
	ModeActivate	Bool	Go to the mode stored in Mode
Input / Output	Mode	Int	Specify mode
Output	ScaledInput	Real	Standardized actual value
	ScaledFeedback	Real	Standardized position feedback
	Output_UP	Bool	Control output up
	Output_DN	Bool	Control output down
	Output_PER	Word	Output value in I/O format
	State	Int	Block status
	Error	Bool	Error flag
	ErrorBits	DWord	Error message

“PID_3Step” is called in the “Cyclic interrupt” (OB30) cyclic interrupt.
The instance data block DB1 for “PID_3Step” is available in the “Technology objects” folder:

Figure 4-8 Opening the instance data block of “PID_3Step”



It can be opened via right-click -> “Open DB editor”.

Apart from the inputs and outputs, the application also accesses the static tags of “PID_3Step”.

A detailed description of the 3-point stepper controller is available in the STEP 7 V12 online help. Select function block “PID_3Step” in the program call (see Figure 4-7) and press F1.

4.2.3 Simulation_OB30 [FC2]

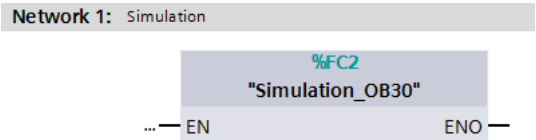
All functions are called from the “Simulation_ OB30” function required for the simulation of the controlled system:

- VALVE [FB101]
- Scale_Real2Real [FC6]
- PROC_C [FB100]
- Scale_ Real2Int [FC5]

The “Simulation_OB30” is called in the same cyclic interrupt as the 3-point stepper controller “PID_3Step”.

For more information, please refer to the following description.

Figure 4-9 Call of function “Simulation_OB30”



VALVE [FB101]

The “VALVE” function block simulates the actuator and, depending on the traversing time, it calculates the valve position and sets the limit switch signals

Depending on the “PER_on” input setting, the valve position is calculated from the digital control signals “InputUP” and “InputDN” or from the analog manipulated variable “Input_PER” of the “PID_3Step” 3-point stepper controller.

The limits for converting the valve position between analog value and floating-point number are adopted from the instance data block of “PID_3Step”.

The specified input limits “PER_max” and “PER_min” are intentionally defined as “Real”, in order to guarantee the compatibility with the specified limits in the instance data block of “PID_3Step”.

When activating the “Reset” input, the calculation of the valve position starts at the lower end position.

Figure 4-10 Calling function block “VALVE_DB”

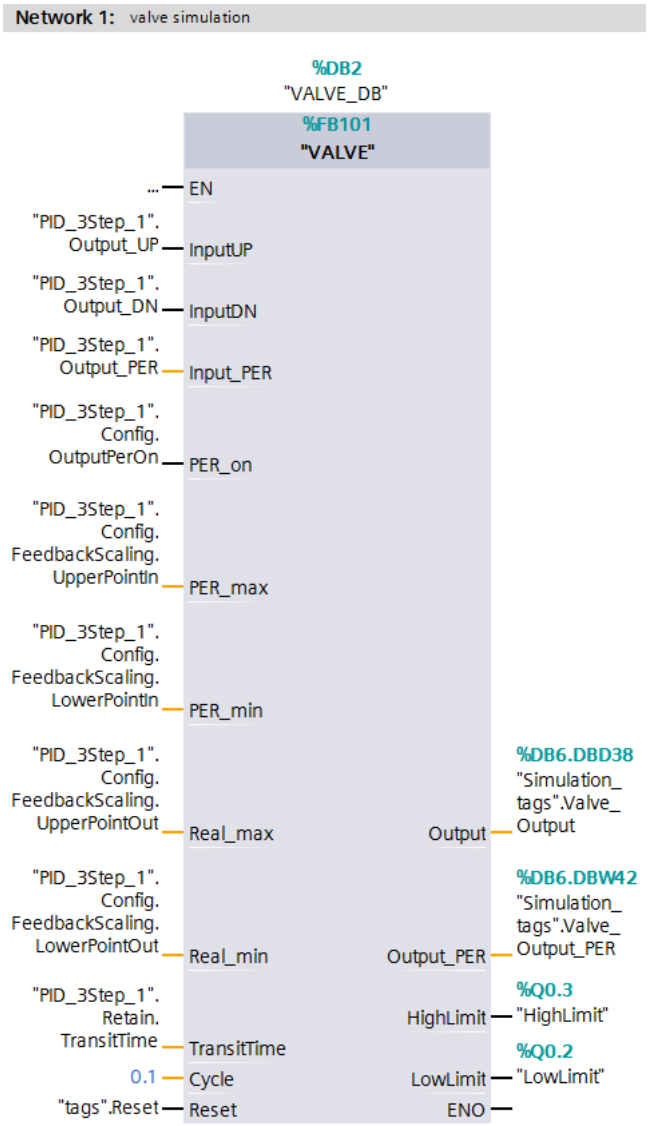


Table 4-4

	Name	Data type	Description
Input	InputUP	Bool	Control signal “Open valve”
	InputDN	Bool	Control signal “Close valve”
	Input_PER	Int	Analog manipulated variable of PID_3Step
	PER_on	Bool	Selection switch, whether InputUP/InputDN or Input_PER is used (Input_PER is used for TRUE)
	PER_max	Real	Upper limit of the analog value of the valve position
	PER_min	Real	Lower limit of the analog value of the valve position
	Real_max	Real	Upper limit of the converted floating-point value for the valve position
	Real_min	Real	Lower limit of the converted floating-point value for the valve position

	Name	Data type	Description
	TransitTime	Real	Traversing time of the value between the end positions
	Cycle	Real	Call interval of the cyclic interrupt
	Reset	Bool	Input for the reset
Output	Output	Real	Calculated valve position (within the “Real_min” and “Real_max” limits)
	Output_PER	Int	Calculated analog valve position (within the “PER_min” and “PER_max” limits)
	HighLimit	Bool	Simulated upper valve end position
	LowLimit	Bool	Simulated lower valve end position

Scale_Real2Real [FC6]

The “Scale_Real2Real” function is used for converting a floating-point number (data type: Real) into a different floating-point number (data type: Real) within predefined boundaries.

This function is used for converting the simulated valve position in the temperature setpoint value as input parameter for the PT1 controlled system simulation.
This temperature setpoint value must be converted to the limits of the water feed into the mixer tap.

Figure 4-11 Calling the “Scale_Real2Real” function

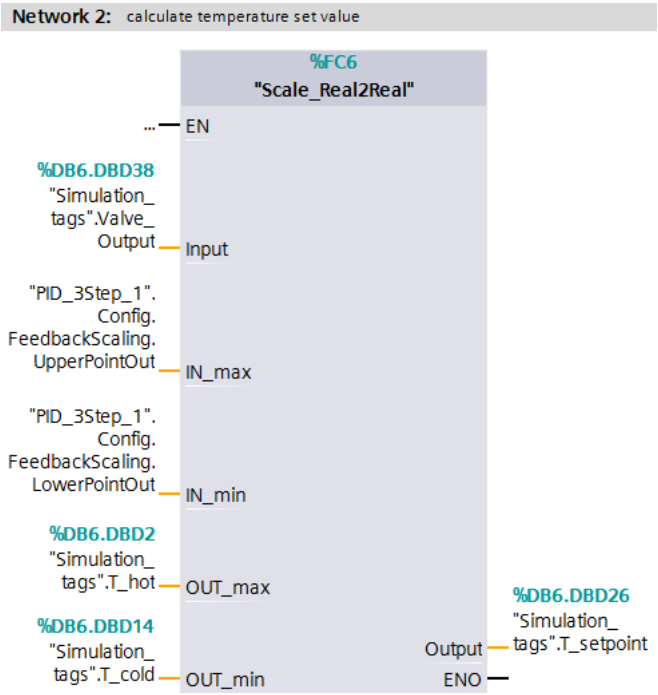


Table 4-5

	Name	Data type	Description
Input	Input	Real	Floating-point value to be converted
	IN_max	Real	Upper limit of the floating point input value
	IN_min	Real	Lower limit of the floating point input value
	OUT_max	Real	Upper limit of the floating point output value
	OUT_min	Real	Lower limit of the floating point output value
Output	Real	Real	Foating point output value

PROC_C [FB100]

Function block “PROC_C” simulates the continuous behavior of a controlled system PT3.

Calculation of the output value is based on the following formula:

$$Output = \frac{Gain \cdot (Input + Disturbance)}{(TimeLag1 \cdot s + 1) \cdot (TimeLag2 \cdot s + 1) \cdot (TimeLag3 \cdot s + 1)} + Offset$$

s = Laplace operator

In the application on hand, controlled system simulation block “PROC_C” is designed as controlled system PT1 with a delay time of 10 seconds (“TimeLag2” and “TimeLag3” are disabled).

Figure 4-12 Calling function block “PROC_C”

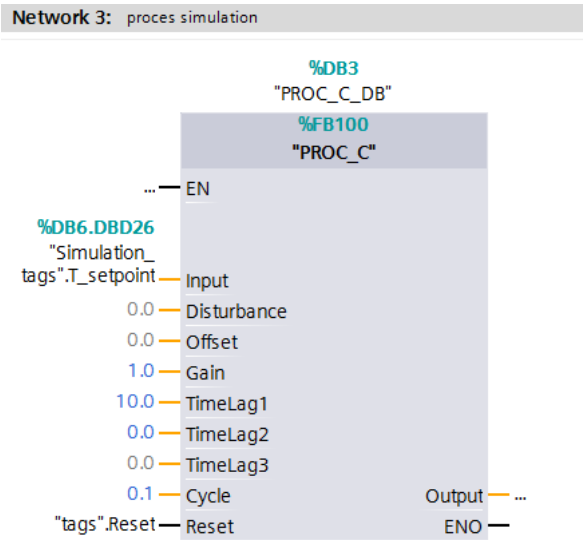


Table 4-6

	Name	Data type	Description
Input	Input	Real	Input value of the simulation of the controlled system
	Disturbance	Real	Disturbance variable
	Offset	Real	Output offset
	Gain	Real	Gain factor
	TimeLag1	Real	Delay time 1 (deactivation for TimeLag1=0.0)
	TimeLag2	Real	Delay time 2 (deactivation for TimeLag2=0.0)
	TimeLag3	Real	Delay time 3 (deactivation for TimeLag3=0.0)
	Cycle	Real	Call interval of the cyclic interrupt
	Reset	Bool	Input for the reset
Output	Output	Real	Calculated output value of the controlled system simulation

Scale_ Real2Int [FC5]

The “Scale_Real2Int” function is used for converting a floating-point number (data type: Real) into an analog value (data type: Int) within predefined boundaries.

The specified output limits “Int_max” and “Int_min” are intentionally defined as “Real”, in order to guarantee the compatibility with the specified limits in the instance data block of “PID_3Step”.

The conversion of the controlled system output (actual temperature value) into an analog value is necessary to be able to simulate the behavior in the case of an error.
For a real controlled system, an error occurs when the actual value sensor fails (e.g. due to wire break).
In the simulation this is achieved by overwriting the analog actual value with a value outside the measuring range (-32768) (see Figure 4-4).

Figure 4-13 Calling the “Scale_ Real2Int” function

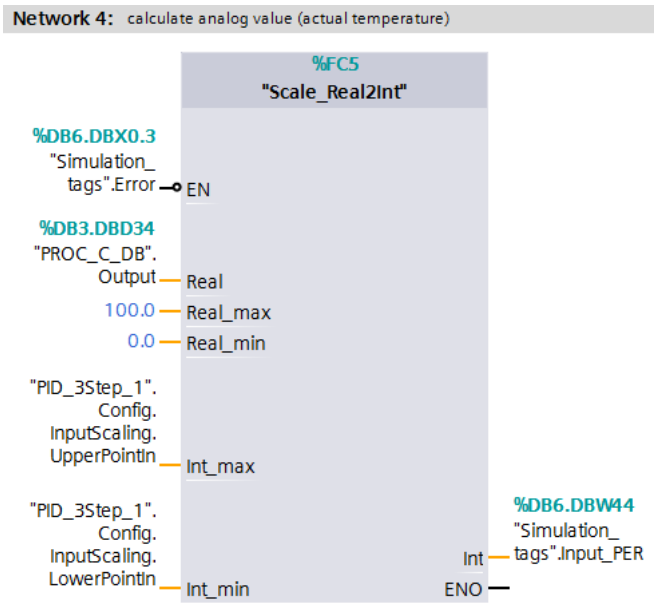


Table 4-7

	Name	Data type	Description
Input	Real	Real	Floating point input value to be converted
	Real_max	Real	Upper limit of the floating point input value
	Real_min	Real	Lower limit of the floating point input value
	Int_max	Real	Upper limit of the analog output value
	Int_min	Real	Lower limit of the analog output value
Output	Int	Int	Analog output value

5 Startup of the Application

5.1 Hardware adaptation

This application was implemented with a CPU 1516-3 PN/DP. Depending on the design of your selected valve, the hardware configuration of your S7-1500 might need adjustment.
The configuration options of S7-1500 for operating the “PID_3Step” 3-point stepper controller are introduced below.

5.1.1 Input signal

The periphery acquires the controlled variable as an analog value. “PID_3Step” offers the conversion of the analog value into the physical unit in the configuration screen.

The modules for the analog value acquisition are listed below.

Controlled variable acquisition and valve position feedback

Table 5-1

Analog inputs	Order number	Resolution
AI 8xU/I/RTD/TC ST	6ES7 531-7KF00-0AB0	16 Bit
AI 8xU/I/ HS	6ES7 531-7NF10-0AB0	16 Bit

5.1.2 Output signal

“PID_3Step” offers the control of the value via 2 digital outputs (in 2 directions) or via an analog output.

Digital outputs

Depending on the power consumption of your digital valve control, you can choose between S7-1500 modules with transistor or relay outputs:

Table 5-2

Digital outputs	Order number	Current (max.)
Transistor (20.4 to 28.8 V)	6ES7 522-1BL00-0AB0	0.5 A
Relay (5 to 250 V)	6ES7 522-5HF00-0AB0	5 A

Analog outputs

Table 5-3

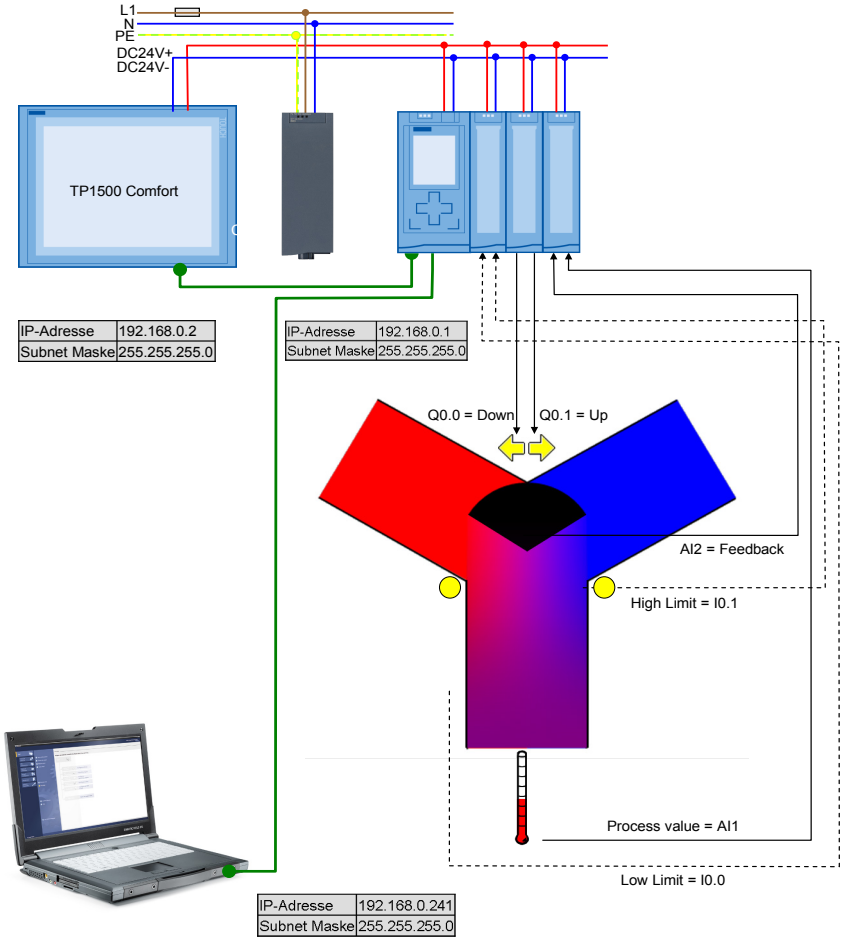
Analog inputs	Order number	Resolution
AI 8xU/I/RTD/TC ST	6ES7 531-7KF00-0AB0	16 Bit
AI 8xU/I HS	6ES7 531-7NF10-0AB0	16 Bit

Note Further information on selecting your periphery and its wiring is available in the respective device manuals.

Hardware installation

The figure below shows the hardware setup of the application.

Figure 5-1 Hardware configuration overview



Installing hardware

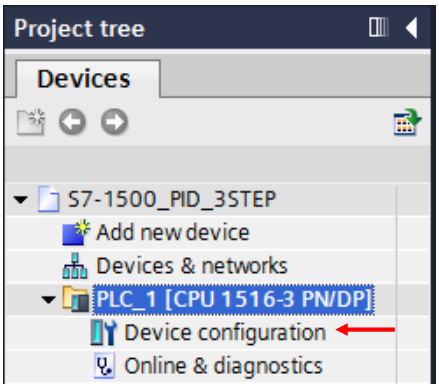
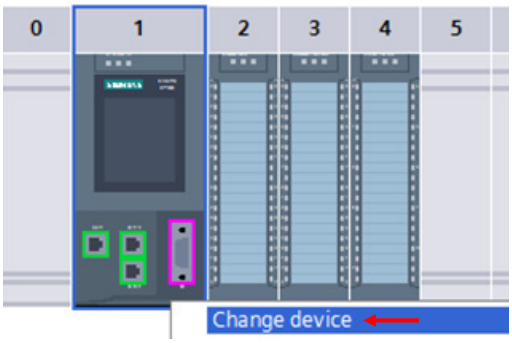
Table 5-4

No.	Action	Comments
1	Adjust the periphery of S7-1500 to the valve you are using.	see chapter 5.1
2	Mount all required S7-1500 components on a DIN rail.	see chapter 2.3
3	Wire and connect all required components as described in the respective device manuals.	
4	Finally, activate the power supply	

5.2 Configuration instructions

Adjusting the device configuration

Table 5-5

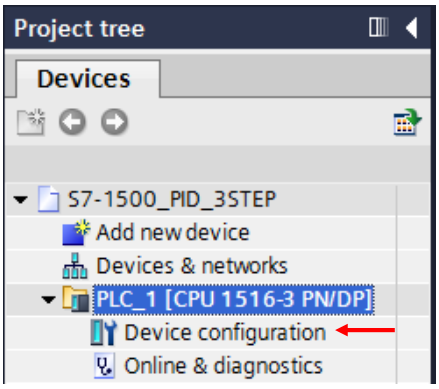
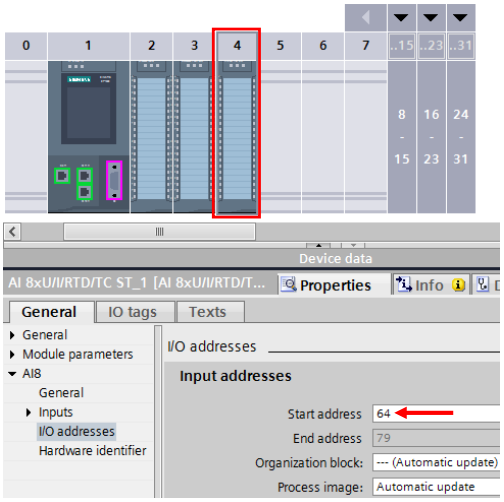
No.	Action	Comments
1.	Connect the S7-1500 controller with your PG/PC. Assign the Ethernet parameters as shown in Figure 5-1.	Assign IP address to S7-1500:
2.	Open the project file (ap12) with STEP 7 V12.	Table 2-3
3.	Open the “Device configuration” of the “PLC_1” controller.	
4.	Adjust the device configuration in the project to the real hardware configuration for your used valve and temperature sensor (chapter 5.1). When using a different CPU, select the configured CPU and activate “Change device…” via right-click. Further information for configuring, mounting, wiring and commissioning the S7-1500 automation system is available in the S7-1500 System Manual.	

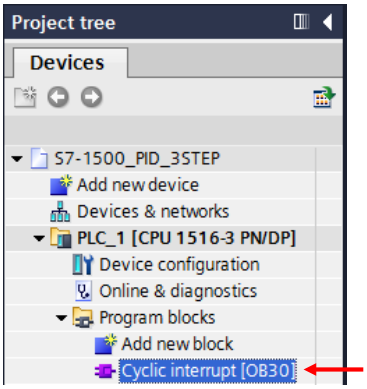
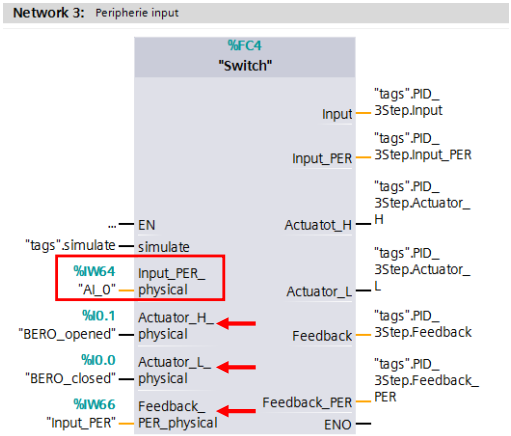
Transferring the I/O addresses

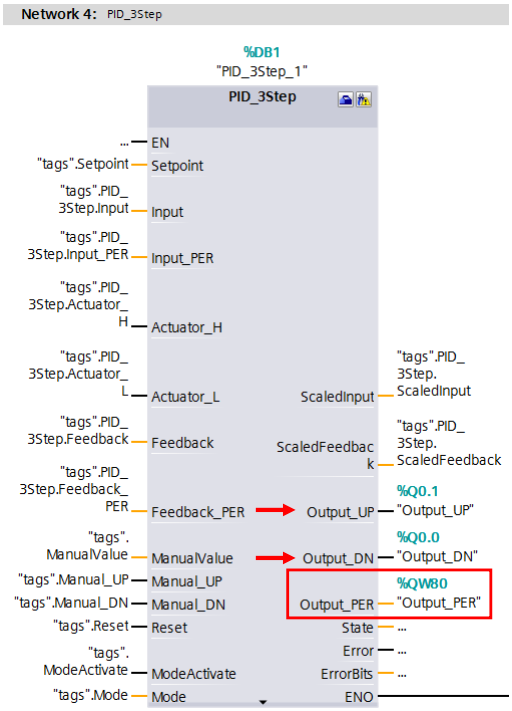
Depending on the changed configuration, you transferred the input or output addresses of the added hardware to the program.

This is illustrated at the example of an AI8 x U/I/RTD/TC ST 16 Bit signal board:

Table 5-6

No.	Action	Comments
1.	Open the “Device configuration” of the “PLC_1” controller.	
2.	In the device view of the CPU you select the signal module. Read the input address of the signal module in menu item “I/O addresses”: • “Start address”: 64 • “End address”: 79 The address read via the analog value is “IW64”.	

No.	Action	Comments
3.	Open the OB30 “Cyclic interrupt” in the control unit of the project.	
4.	Since the actual value is read via the signal board as the temperature, you transfer input word **IW64** to the “Input_PER_physical” parameter of the “Switch” function in network 3. Furthermore, you have the option to adjust the • digital input addresses for the end positions of the valve (Actuator_H_ physical / Actuator_L_ physical) • analog input address for the feedback signal of the valve position (Feedback_PER_physical)	

No.	Action	Comments
5.	If using a valve with analog control you transfer the address of the analog output in network 4. Furthermore, you can also adjust the digital control signals at the I/O: • Output_UP • Output_DN	

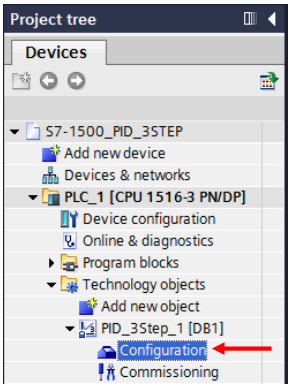
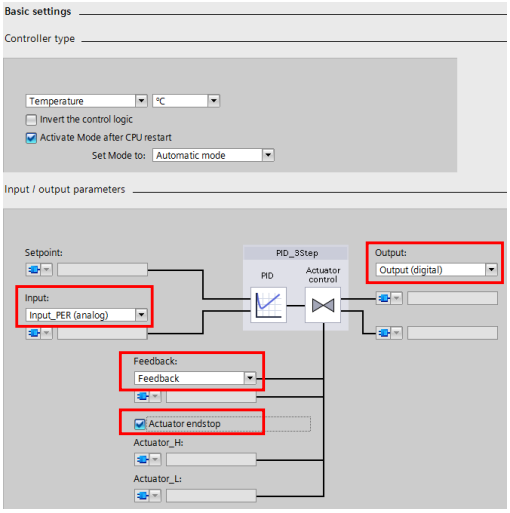
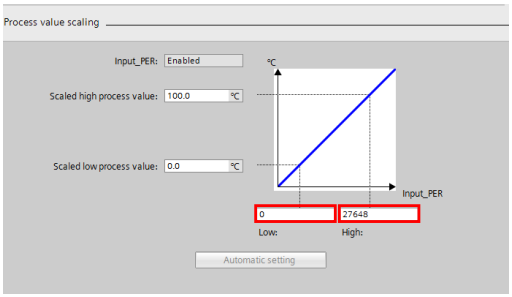
Configuring the PID controller

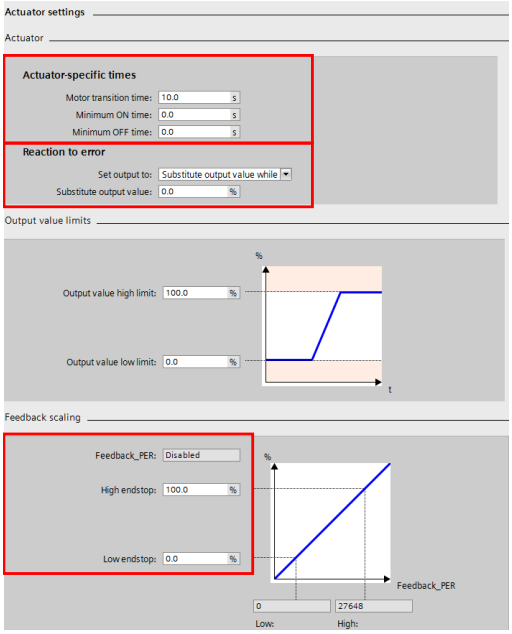
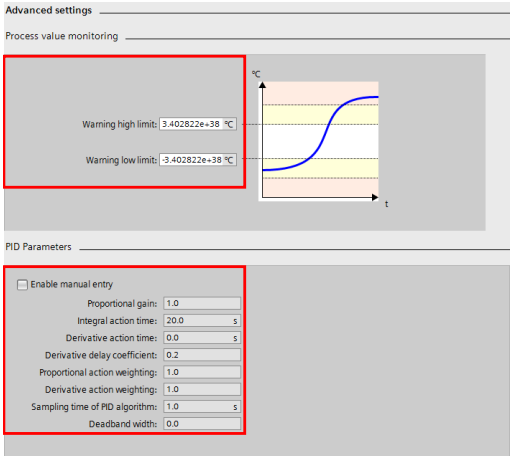
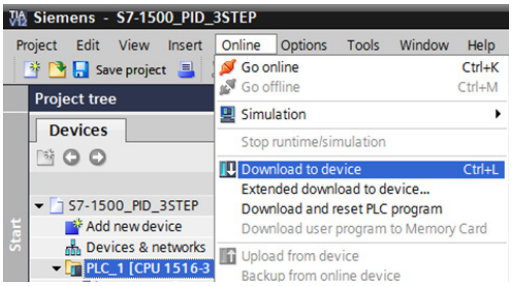
The configuration of the “PID_3Step” technology object defines the function principle of the 3-point stepper controller.

The settings made determine the default values used by the PID controller when restarting after a cold or warm start (e.g. power failure).

A more detailed description is available in the TIA Portal V12 online help.

Table 5-7

No.	Action	Comments
1.	Open the configuration editor by selecting “PLC_1 > Technology objects > PID_3Step_1 > Configuration”.	
2.	Open the “**Basic settings**”. Here you determine the properties of the valve you are using: • digital or analog control • does the valve provide a feedback of the valve position • does the valve have digital end position switches **Note:** Setting the controller type (here: Temperature) with the unit (here: °C) is only performed for labeling the axis correctly in the Startup wizard.	
3.	Open the “**Process value scaling**”: Here you determine the limits of the process value (Input_PER). **Note:** please ensure that the correct settings for upper and lower actual value (here: 0 to +100°C), since the controller turns inactive when these limits are violated!	

No.	Action	Comments
4.	Open the “**Actuator settings**”. **“Actuator-specific times”** If your used valve does not give any position feedback, neither analog nor digital, the “Motor transition time” must be specified here as precisely as possible. For adjusting the actuator inertia you can specify minimal switch ON/OFF times. **“Reaction to error”** Determine whether the current valve position or a substitute output value as a percentage shall be approached in the case of an error. **“Feedback scaling”** When using a valve with position feedback (Feedback_PER), you determine the limits here.	
5.	Open the “**Advanced settings**”: **“Process value monitoring”** Here you can specify warning limits where a respective warning bit will be activated when exceeded or fallen short of. **“PID Parameters”** If you do not wish to use the self-optimization function, please specify the control parameters manually. These values are written to the instance data block of the “PID_3Step” and adopted as actual values after a cold start (loading project into the controller).	
6.	Save the project. Then select the program folder of the S7-1500 and transfer the program to the controller via “Online > Download to device”. Make sure that the LED of the S7-1500 controller indicates the “RUN” status.	

Note

The CPUs of the S7-1500 series apply changes to **DB start values** only during the next **STOP-RUN** transition.

Please consider this behavior when making changes to the data blocks.

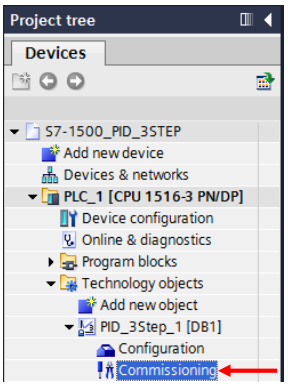
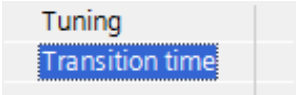
5.3 Commissioning the 3-point stepper controller

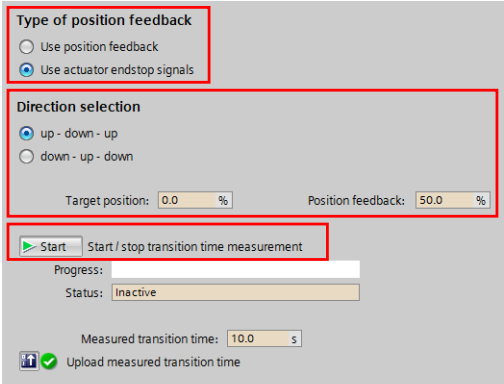
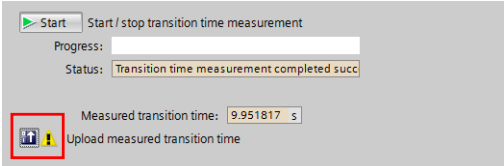
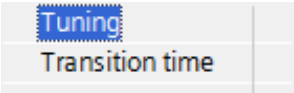
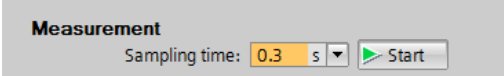
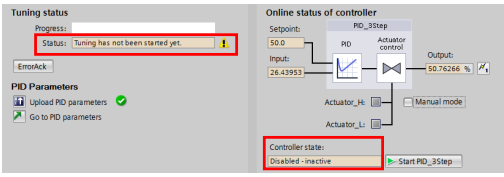
Configure the 3-point stepper controller in the startup editor for the automatic settings during startup and for the automatic setting during operation.

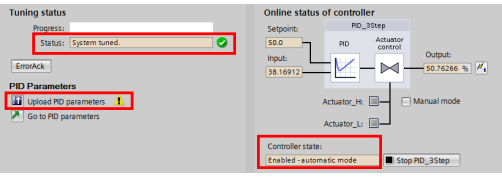
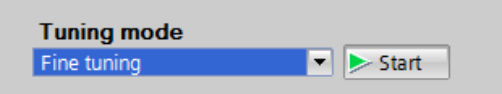
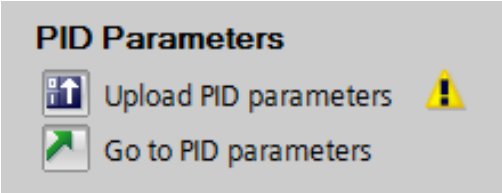
The settings made determine the default values used by the PID controller when restarting after a cold or warm start (e.g. power failure).

A more detailed description is available in the TIA Portal V12 online help.

Table 5-8

No.	Action	Comments
1.	Open the Commissioning editor by selecting “PLC_1 > Technology objects > PID_3Step_1 > Commissioning”.	
2.	Connect the programming device to the CPU by selecting “PLC_1” and clicking to the “Go online” button.	
3.	Open the “Transition time” folder in the Commissioning editor.	

No.	Action	Comments
4.	Depending on the “Type of the position feedback” you can measure the transition time of your valve here: • When using the stop signals of the actuator you can decide whether the “Direction selection” shall be “up-down-up” or “down-up-down”. • When using the position feedback, you must assign a target position with a distance of at least 50% from the current position feedback. • Without position feedback, the transition time must be specified as precisely as possible. Start the transition time measurement.	
5.	After completion, upload the measured transition time into the project. The measured transition time is written to the instance data block of “PID_3Step” as the start value and restarts with this transition time after a cold or warm start (e.g. power failure).	
6.	Open the “Tuning” folder in the Commissioning editor.	
7.	Start the measurement.	
8.	Without manual preassignment of the PID parameters (Table 5-7, step 5) the status indicates that tuning has not yet been started, and after the first startup of the CPU the controller is in Disabled (inactive) mode.	

No.	Action	Comments
9.	From the inactive state you can only start with “Pretuning”. Selecting “Fine tuning” starts pretuning followed by a fine tuning. Specify a setpoint in central area of the actual value range (e.g. via a monitoring table). Note: The start value of the setpoint value has already been predefined accordingly. Start the pretuning process.	
10.	After successful pretuning, the controller goes to automatic mode. The determined values can be viewed via “Go to PID parameters”. “Upload PID parameters” writes the determined values as start values into the instance data block of “PID_3Step”.	
11.	Specify a setpoint in central area of the actual value range (e.g. via a monitoring table). Note: The start value of the setpoint value has already been predefined accordingly. In automatic mode you can now directly start the fine tuning.	
12.	After the successful fine tuning of the PID parameters, the determined PID parameters can be loaded values into the instance data block of “PID_3Step” as start values.	

Note

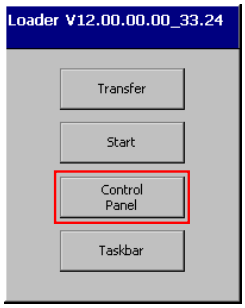
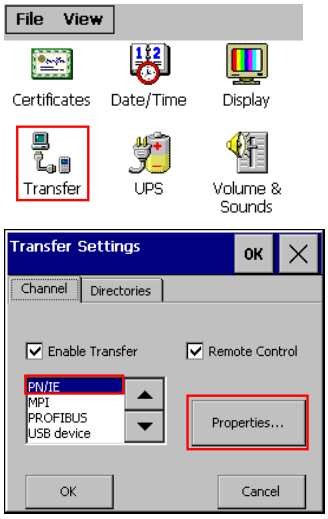
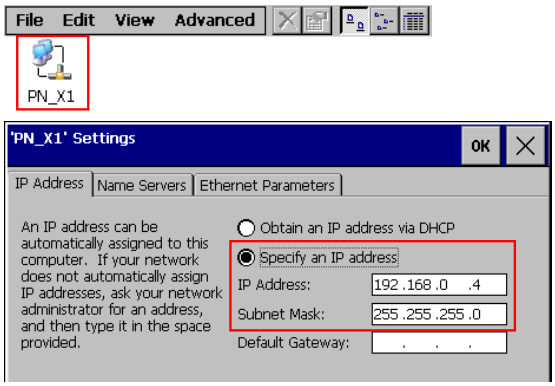
The PID parameters are stored retentively in the instance data block of the “PID_3Step” 3-point stepper controller.
During a warm start (restored power) the last processed values remain.
The start values are only loaded during cold start (transferring the project in STOP mode).

5.4 HMI project part

Configuring the HMI

When using the TP1500 Comfort Panel as operator panel you set the project-specific IP address (see Figure 5-1).

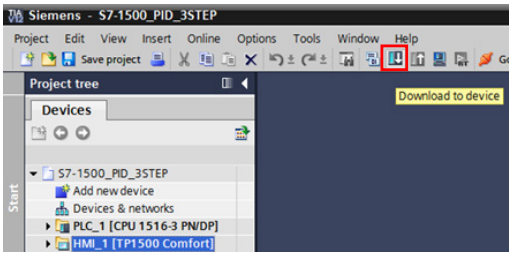
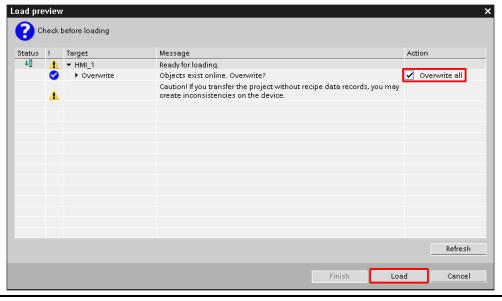
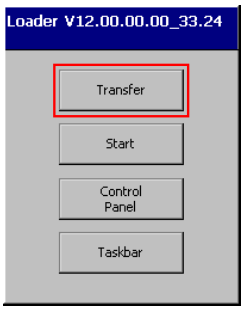
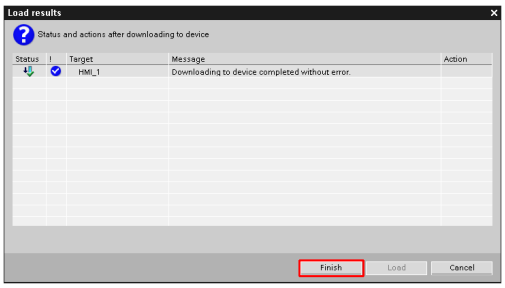
Table 5-9

1.	• Select the “Control Panel” button to open the properties of the control panel of the Boot Loader.	
2.	• Select the “Transfer” button to open the “Transfer Settings” dialog box. • Activate “Enable Transfer”. • Activate "Remote Control". • Select the “PN/IE” data channel and adjust its parameters via "Properties...".	
3.	• Open the "PN_X1" entry. The “'PN_X1' Settings” dialog box opens. • Select the specific address. • Enter the - IP address = 192.168.0.04 and the - Subnet Mask= 255.255.255.0 via the screen keyboard. • Select “OK” to close the dialog box and apply the entries.	

Loading the HMI project part into the TP1500

For the transfer, you connect your PG/PC with the HMI

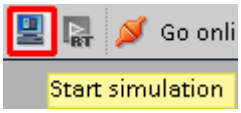
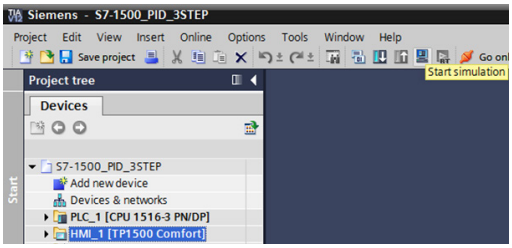
Table 5-10

No.	Instruction	Note / Screen
1.	• Select the “HMI_1 [TP1500 Comfort]” operator panel folder. • Press the “Download to device” button to download the HMI project part to the TP1500.	
2.	• If necessary, check the “Overwrite all” option. • Press the “Load” button	
3.	• Depending on the operator panel setting, you have to activate the transfer in the Loader menu of the TP1500 via the “Transfer” button.	
4.	• Once the successful result message is displayed, select the “Finish” button to finish downloading.	

Starting PC runtime

If the PG/PC is to be used as operator panel, start the PC runtime as follows:

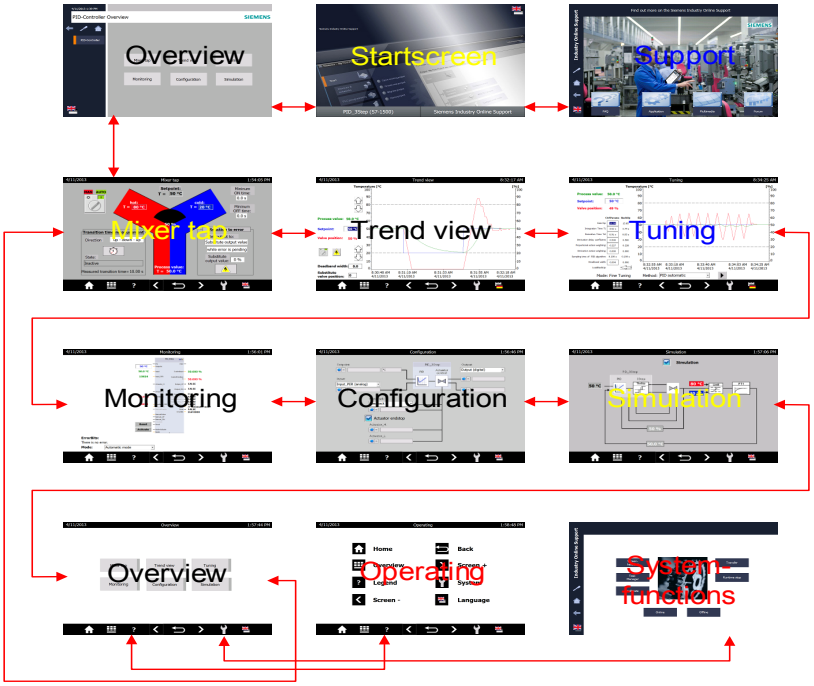
Table 5-11

No.	Instruction	Note / Screen
1.	• Select the “HMI_1 [TP1500 Comfort]” operator panel folder. • Click the “Start simulation” button. 	

6 Operating the Application

Overview

Figure 6-1 Overview - Operating the application

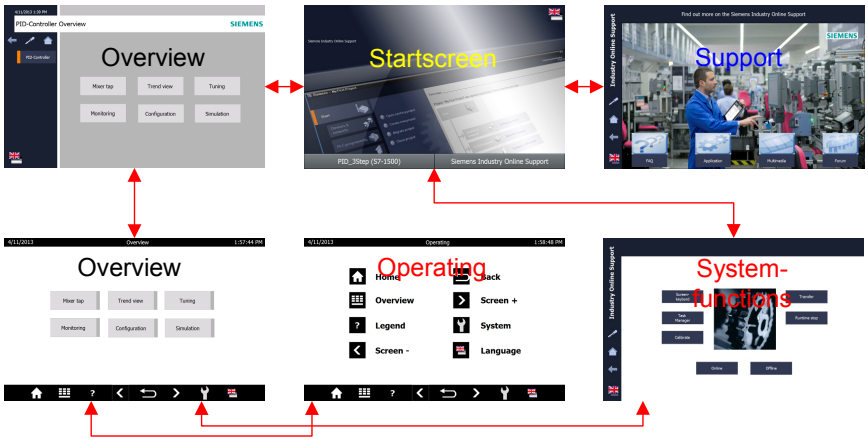


The user interface consists of 12 screens:

- Start screen (Welcome)
- Support (Information on the Siemens Industry Online Support)
- Overview of application-specific screens:
  - Mixer tap
  - Trend view
  - Tuning
  - Monitoring
  - Configuration
  - Simulation
- Operation (explanation of the symbol)
- System functions of the HMI panel

6.1 Overview of the application-specific screens

Figure 6-2 Overview of the application-specific screens



6.1.1 Start screen

Figure 6-3 Start screen

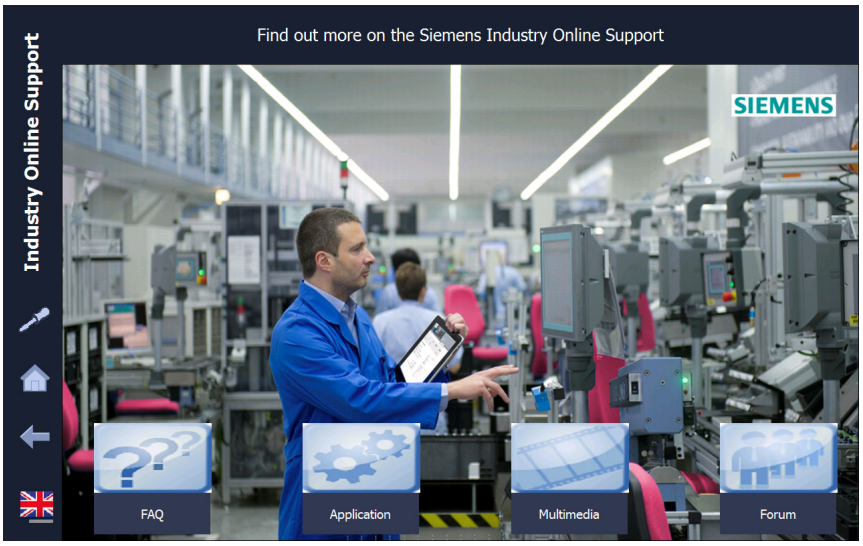
From the start screen, you get to the:

- overview via the “PID_3Step (S7-1500)” button
- support information via the “Support” button.

6.1.2 Support description

This support description gives information on the Siemens Industry Online Support.

Figure 6-4 Support description



-  enables you to toggle between German and English language.
-  takes you to the preceding screen.
-  takes you back to the Home screen.
-  takes you to the System functions.

6.1.3 Overview screen

From the overview screens, the buttons take you to the appropriate application-specific screens.

Figure 6-5 Overview screen

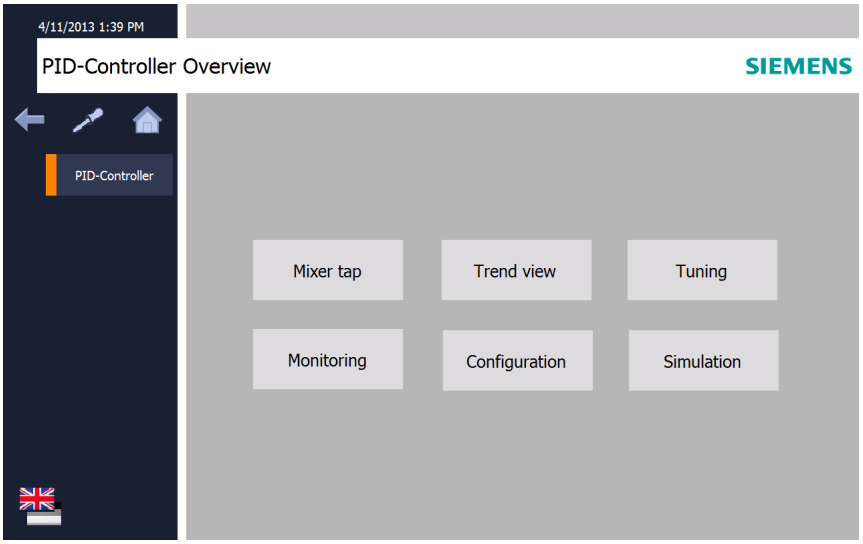
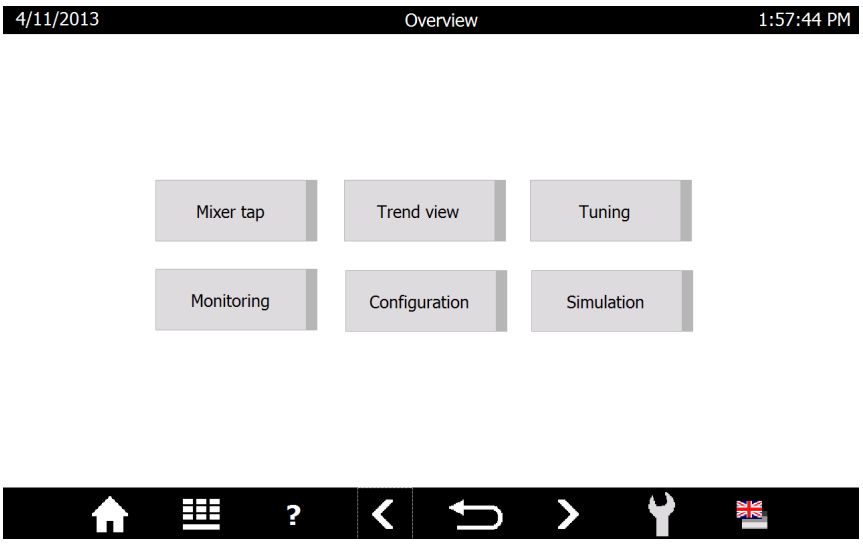


Figure 6-6 Overview screen

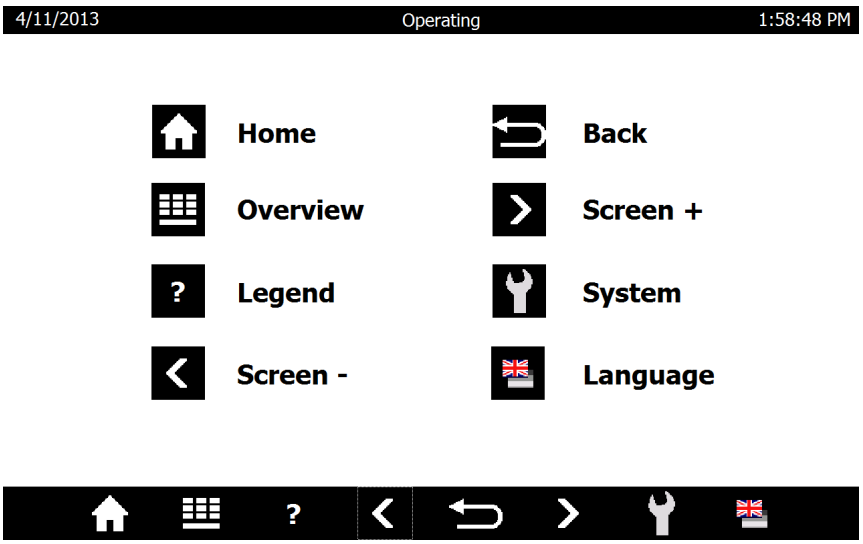


- The header contains the date, the screen title and the local time.
- ? takes you to the explanation of symbols in the footer.

6.1.4 Operating screen

The Operating screen explains the task of the individual symbols in the footer.

Figure 6-7 Operating screen

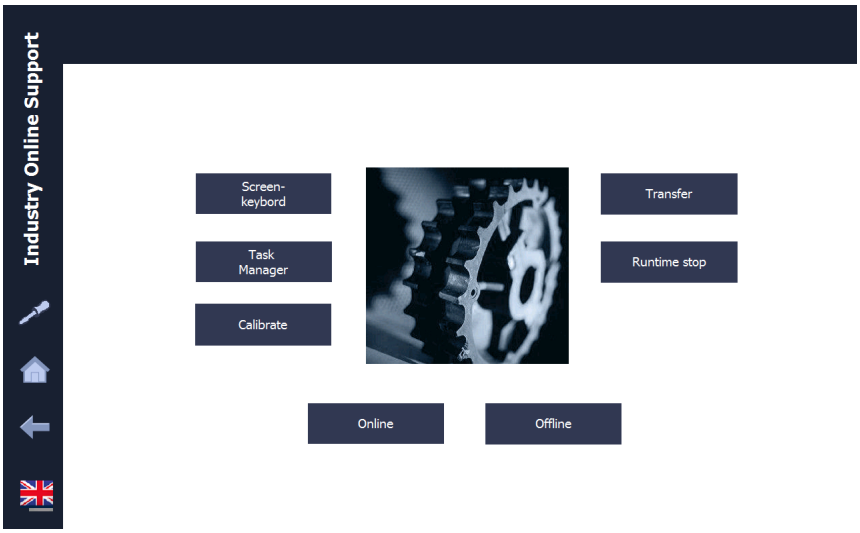


- takes you to the Home screen (Figure 6-3).
- takes you to the Overview screen (Figure 6-6).
- ? takes you to the Operating screen (this screen).

- takes you to the preceding screen in the order of the application-specific screens (Overview, Mixer tap, Trend view, Tuning, Monitoring, Configuration and Simulation).
- takes you to the last screen called up.
- takes you to the next screen in the list:
- takes you to the System functions (Figure 6-8).
- enables you to toggle between German and English language.

6.1.5 System functions

Figure 6-8 System functions screen

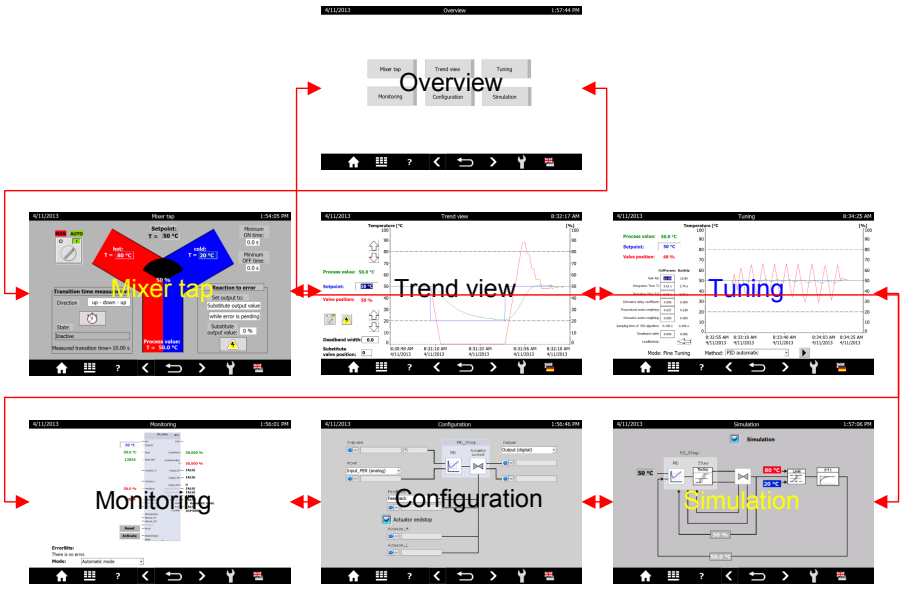


The HMI system function enables you to:

- switch on the screen keyboard
- call up the Windows Task Manager
- calibrate the touch panel
- go online and offline
- terminate Runtime
- go to the transfer mode (where you can make settings in the control panel)

6.2 Overview of application-specific screens

Figure 6-9 Overview of application-specific screens:



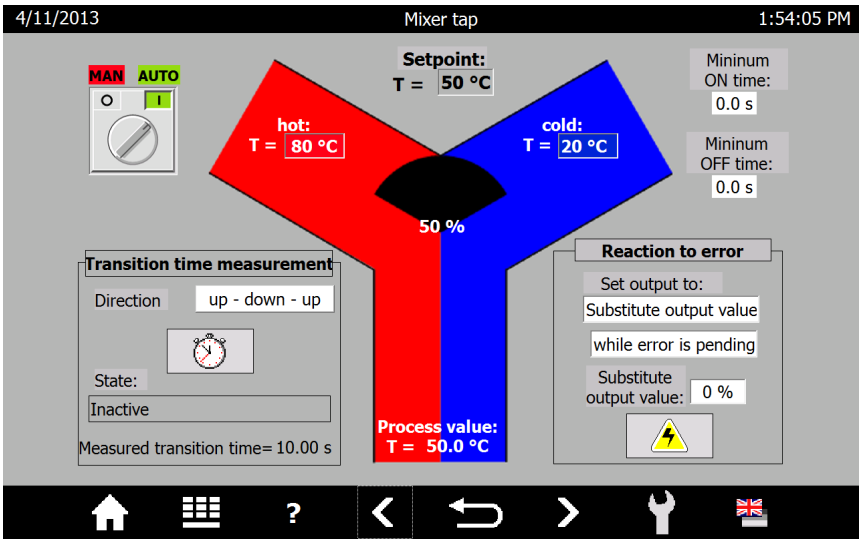
The Overview screen (Figure 6-6) takes you to the application-specific screens via the respective button.

- ❮ takes you to the “Simulation”.
- ❯ takes you to the “Mixer tap”.

The sequence of the application-specific screens is shown in Figure 6-9.

6.2.1 Mixer tap

Figure 6-10 Mixer tap screen



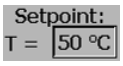
The “Mixer tap” screen shows the mixer tap with the inflow of hot and cold water.

The vertical distribution between hot and cold water in the outflow is animated depending on the valve position.

The header of all application-specific screens contains the date, the screen title and the local time.

Manual and automatic mode

enables you to switch between manual and automatic mode.

In automatic mode, you can assign the mixer temperature setpoint via 

(value range 1 to 99 °C).

In manual mode you can

- specify the valve position via 

(value range 0 to 100 %) when using a valve with continuous position feedback
- change the valve position by +/-5% via  when using a valve without continuous position feedback.

Transition time

Depending on the type of the position feedback you can measure the transition time of your valve in automatic mode:

- When using the stop signals of the actuator you can choose between the direction up - down - up or down - up - down.
- When using the continuous position feedback, the application sets the target position to
  - NewOutput: 0 % at current valve position >= 50%
  - NewOutput: 100 % at current valve position <50%
- Without position feedback (stop signals or continuous position feedback), the transition time must be specified as precisely as possible via Target transition time: 9.95 s.

With position feedback you start the transition time measurement via  .

The following status is displayed: Close valve completely

After successful measurement, the measured transition time is displayed:
Measured transition time= 9.95 s

NOTICE	**In order to start up with the measured transition time after a power failure, this value must be written to the instance data block of "PID_3Step" as a start value.** **The commissioning wizard offers this function (Table 5-8 , Step 5).**

Actuator switching times

For adjustment to possible actuator inertia you can vary

- the Mininum ON time: ("minimal switch-on time") and
- the Mininum OFF time: ("minimal switch-off time").

NOTICE	**In order to start up with these settings after a power failure, this value must be written to the instance data block of "PID_3Step" as a start value.** **The configuration wizard offers this function (**Table 5-7**, Step 4) at the subsequent transmission of the instance data block.**

Reaction to error

Determine whether in case of an error

- the current valve position [Current value] or
- a substitute output value [Substitute output value] must be specified via [Substitute output value:] (value range 0 to 100 %)
  - for the duration of the error [while error is pending] or
  - permanently [ ]

shall be controlled.

NOTICE	**In order to save this presetting through a power failure, this value must be written to the instance data block of "PID_3Step" as a start value.** **The configuration wizard offers this function (**Table 5-7**, Step 4) at the subsequent transmission of the instance data block.**

Controlled system simulation

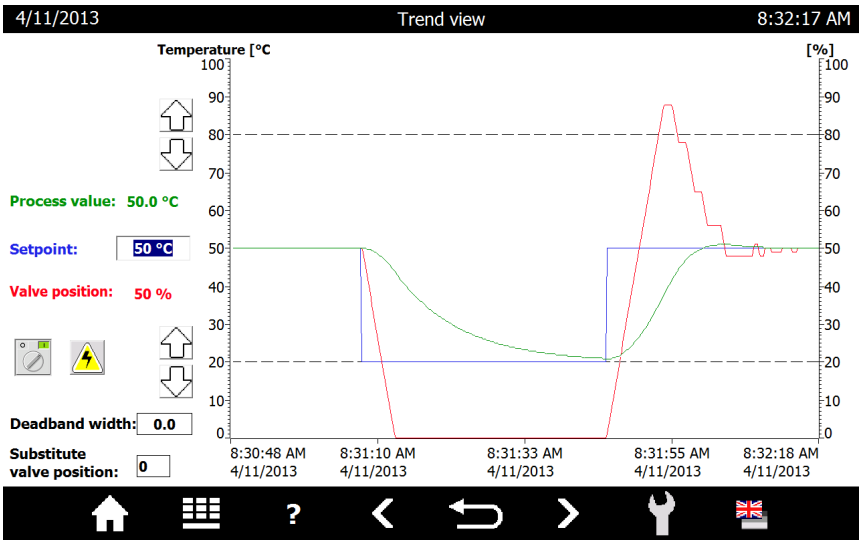
In controlled system simulation

- in automatic mode, the behavior can be simulated in the case of an error via [⚡] (switching on and off)
- the hot water temperature via [hot: T = 80 °C] in the range between 70 to 90 °C.
- the cold water temperature via [cold: T = 20 °C] in the range between 10 to 30 °C

can be varied for disturbance variable control.

6.2.2 Trend view

Figure 6-11 Trend view screen



The “Trend view” screen shows the time sequence over 90 seconds.

- the mixing temperature Setpoint (scale center)
- the actual mixing temperature value Process value (scale left)
- the valve position Valve position (scale right)

Manual and automatic mode

enables you to switch between manual and automatic mode.

In automatic mode, you can assign the mixer temperature setpoint via Setpoint: 49 °C (value range 1 to 99 °C).

In manual mode you can

- specify the valve position via Manual value: 48 % (value range 0 to 100 %) when using a valve with continuous position feedback
- change the valve position by +/-5% via when using a valve without continuous position feedback.

Dead band width

The dead band suppresses the noise fraction in the steady controller state. Specify the size of the deadband via Deadband width: 0.4.
At a deadband width of 0.0 the dead band is switched off.
The smaller the deadband width you choose, the more exactly the attempt of the controller to adjust the controller to the actual value is. This higher precision, however, often leads to a more frequent control of the valve.

Reaction to error

If by default the valve approaches the substitute output value in the case of an error, you specify that value via "Substitute valve position"
Substitute valve position: 33.

Controlled system simulation

In controlled system simulation operation, the behavior can be simulated in automatic mode in the case of an error via (switching on and off)

The dashed lines represent the inflow temperatures:

- the upper one for hot water (range between 70 to 90 °C) and
- the bottom one for cold water (range between 10 to 30 °C).

In controlled system simulation mode, the respective inflow temperature can be varied

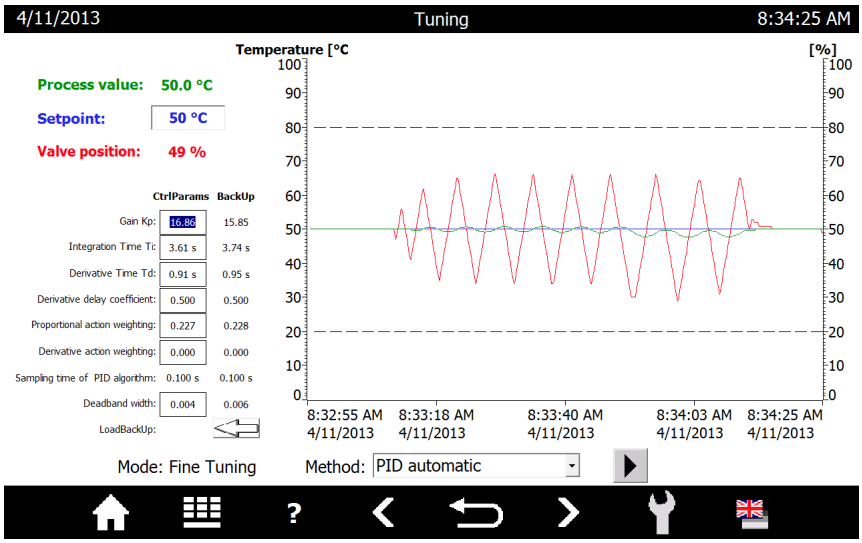
- by +10°C via and
- by -10°C via

can be varied for disturbance variable control.

When specifying the setpoint above the hot or below the cold water temperature, the simulated actual temperature value is limited by this.

6.2.3 Tuning

Figure 6-12 Tuning screen



The Tuning screen provides the following options

- for pretuning from the inactive controller state or
- fine tuning from the automatic mode.

For pretuning you can chose between the following tuning methods:

- Chien, Hrones, Reswick PID
- Chien, Hrones, Reswick PI

For fine tuning you can chose between the following tuning methods:

- PID automatic
- PID fast
- PID slow
- Ziegler-Nichols PID
- Ziegler-Nichols PI
- Ziegler-Nichols P

Pressing  starts the selected tuning method.

Note

Enter a setpoint value as close to the central field of the actual value range to avoid cancelling the tuning by reaching the limit.

During tuning, the setpoint is frozen, the tuning status and the percentage progress is displayed.

After successful tuning, the determined controller parameters are displayed in the “CtrlParams” column and the controller parameters prior to tuning are moved to the “BackUp” column.

The secured “BackUp” parameter set can be loaded back into the controller with  .

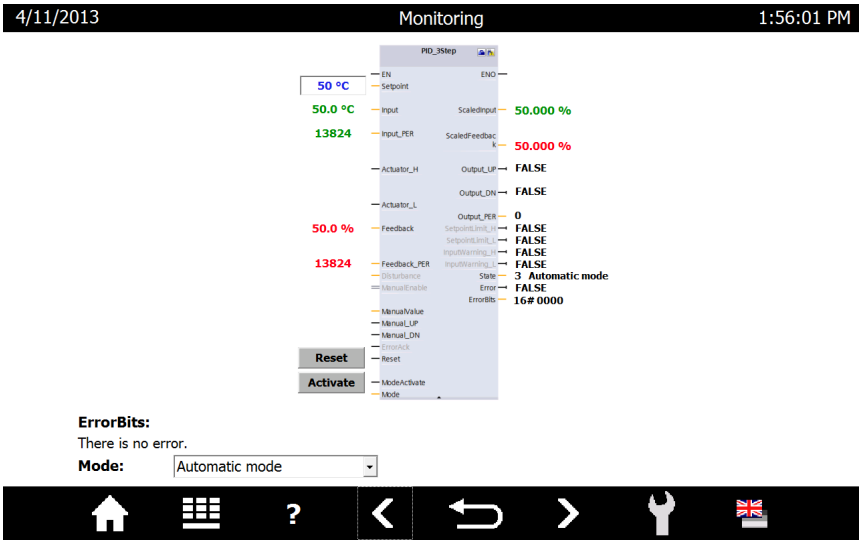
The current controller parameters (“CtrlParams”) can also be edited manually.

Note

The current controller parameter set (“CtrlParams”) is retentive and is also loaded again after power failure.
In order to use these parameters for starting after a cold start, they must be written as into the instance DP of “PID_3Step” as a start value.
The commissioning wizard offers this function (Table 5-8 , Step 10).

6.2.4 Monitoring

Figure 6-13 Monitoring screen



The Monitoring screen shows the online status of the “PID_3Step” 3-point stepper controller.

You can:

- view all inputs and outputs
- edit the following parameters:
  - setpoint in automatic mode (“Setpoint”)
  - switching between manual and automatic mode (“Mode” and “ModeActivate”)
  - Manual specification of the position in manual mode for valves with position feedback (“ManualValue”)
  - Step-by-step position change in manual mode for valves without position feedback (“Manual_UP” and “Manual_DN”)
  - Resetting the 3-point stepper controller (“Reset”)

Note

In this application, the Reset button performs a restart of the “PID_3Step”, “VALVE” and “PROC_C” blocks.
The intermediate values of the controller are reset here.
The PID parameters, however, are retained.
Subsequently, the controller starts again in automatic mode.

The operating mode of the 3-point stepper controller can be specified via the “Mode” parameter. A rising edge at the “ModeActivate” input changes the three point stepper controller to the given mode.

In the case of errors (“Error” = TRUE), the “ErrorBits” output gives the error code and the textual description.

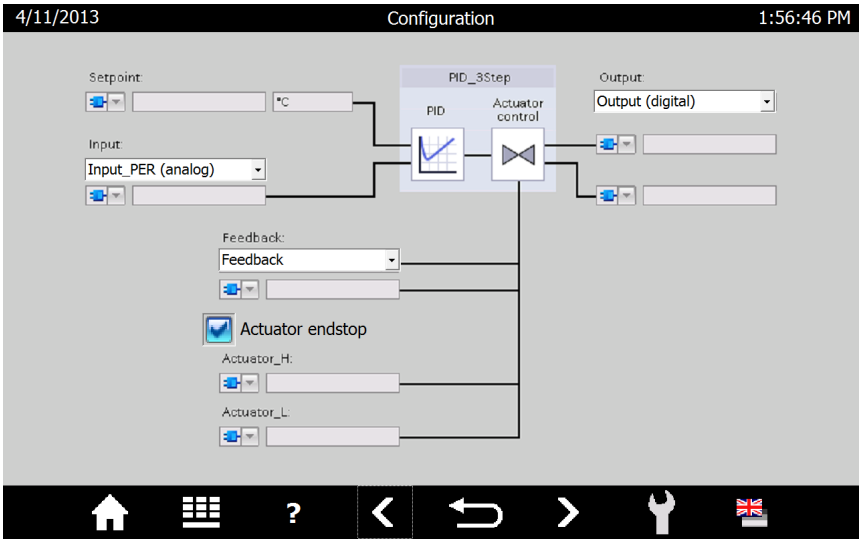
The occurring error messages are also displayed globally.

Errors must be acknowledged via Acknowledge Error.

Note A detailed description of the error messages (ErrorBits) is available in the STEP 7 V12 online help.

6.2.5 Configuration

Figure 6-14 Configuration screen



The Configuration screen matches the basic settings of the configuration wizard (Table 5-7, Step 2).

Here, you can change the following specifications during runtime:

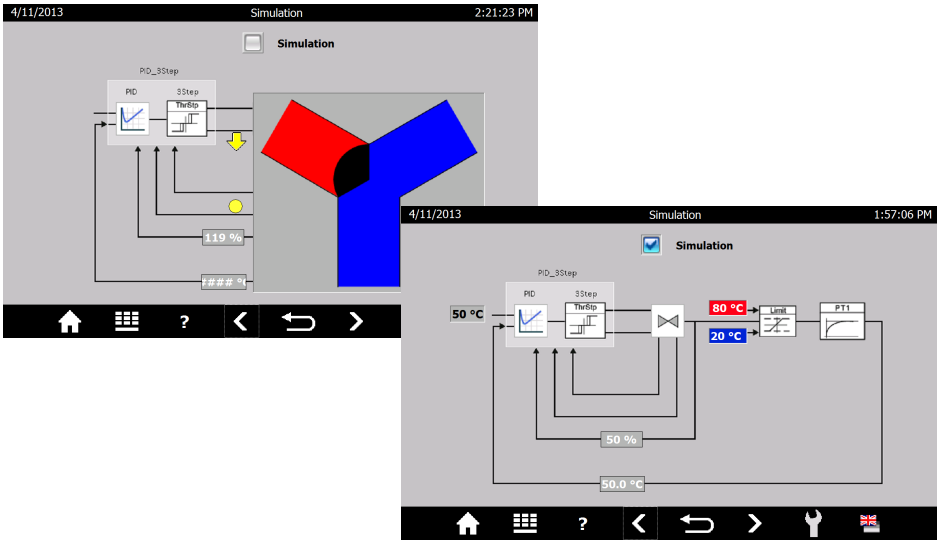
- Actual value input: floating-point number (“Input”) or analog (“Input_PER”)
- Position feedback of the valve:
  - no feedback (standard)
  - feedback signal via floating-point number (“Feedback”)
  - analog feedback signal (“Feedback_PER”)
- Valve provides end stop signals or not
- Manipulated variable output: via 2 direction control (“Output (digital)”) or analog (“Output_PER”)

This screen familiarizes with the settings of the 3-point stepper controller and its characteristics (especially for the simulation mode).

NOTICE	**In order to save this configuration through a power failure, these values must be written to the instance data block of "PID_3Step" as a start value. The configuration wizard offers this function (**Table 5-7**, Step 2) at the subsequent transmission of the instance data block.**

6.2.6 Simulation

Figure 6-15 Simulation screen

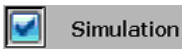


The Simulation screen enables switching between a real and a simulated control system.

The block diagram of the "PID_3Step" 3-point stepper controller is displayed with:

- the setpoint specification
- the actual value
- the valve feedback:
  - position feedback
  - end stop signal "closed"
  - end stop signal "open"
- the digital valve control signals
  - Open
  - Close.

If the simulation is not switched on, the controller receives the signals from the controller I/O (Table 5-6, Step 4).

When the simulation  is switched on, the screen shows the block diagram structure as the input signals for the controller are calculated:

The digital valve control signals feed a valve simulation  , which supplies the valve feedback.

The percentage value of the valve position feedback is limited 

by the hot 

and cold 

water temperature and supplies the setpoint temperature value for the controlled system.

The output of the controlled system simulation block PT1 

supplies the actual temperature value.

7 Internet Links

This table contains a selection of links on further information.

Table 7-1

	Topic	Title
\1\	SIMATIC S7-1500 Automation System Manual	http://support.automation.siemens.com/WW/view/en/59191792
\2\	Signal Modules Manual	http://support.automation.siemens.com/WW/view/en/57251228/133300
\3\	STEP 7 Basic V12.0 System Manual	http://support.automation.siemens.com/WW/view/en/68113678
\4\	This entry	http://support.automation.siemens.com/WW/view/en/68011827

8 History

Table 8-1

Version	Date	Modifications
V1.0	04/2013	First version